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The Zeeman Congress

By OTTO STRUVE

In 1896 Pieter Zeeman discovered the splitting of the spectral lines when the emitting light source is placed in a strong magnetic field. He had been led to expect such a phenomenon from the theoretical work of Thomson and Tait, but his early experiments gave negative results. Zeeman persevered in his attempts, especially after he had learned from a book by Maxwell that Faraday had already in 1862 carried out similar experiments, but had also failed to find a difference in the character of the emitted radiation. Zeeman's great discovery was facilitated by the fact that he had at his disposal an excellent diffraction grating ruled by Rowland at Johns Hopkins University. With the help of this grating he examined the yellow D lines of sodium, and found them to be appreciably broadened when the flame containing the vapor of sodium was placed in a field of some 10,000 gauss, with the outer edges of the lines showing circular polarization in opposite directions, when the observations were made parallel to the magnetic lines of force. This type of polarization had been predicted by H. A. Lorentz at Leiden. With still greater dispersion Zeeman resolved the broadened lines into several symmetrically spaced components.

The tremendous impact of this discovery upon the development of spectroscopy and atomic theory is well known, and indirectly this development has had a great influence upon astrophysics. However, more direct was the influence of the Zeeman effect in solar research, when, in 1908, George E. Hale discovered the magnetic splitting of the absorption lines in the spectra of sunspots.

In order to commemorate the 50th anniversary of the discovery of the Zeeman effect the Netherlands Physical Society, together with the Zeeman Laboratory and the Physical Laboratory of the University of Amsterdam, organized a congress of spectroscopists at Amsterdam between September 17 and 22, 1946. The idea of this congress came "as a day-dream" to Zeeman's successor at Amsterdam, Professor C. J. Gorter (who has since been appointed to the chair of physics at Leiden), when, during the German occupation and the terrible months of starvation, men in and out of concentration camps frequently engaged in the pastime of day-dreaming. The scientists of Holland, perhaps more than those of any other country, suffered from their prolonged isolation. The congress was intended to relieve this situation and to enable

spectroscopists from many countries to discuss their problems.

The physicists of Holland deserve our admiration for the manner in which they had carried out the necessary preparations. Although conditions have greatly improved since 1944 and 1945, it was no easy task to organize an international congress at this time. The muncipality of Amsterdam and the Government of the Netherlands generously paid part of the expenses. The visiting delegates were entertained in private homes; most of their meals and several excursions (to the great dykes of the Zuyder Zee, which were blown up by the retreating Germans, but have since been repaired; to the imposing physical laboratory of the Philips Electrical Works at Eindhoven; to the Universities of Leiden or Utrecht; and through the picturesque canals of old Amsterdam) were provided by the organizational committee under the chairmanship of Dr. S. R. deGroot.

The meeting was opened by a lecture on "Fifty Years of Zeeman Effect" by Professor C. J. Bakker, who has recently been appointed to succed Professor Gorter as the director of the Zeeman Laboratory. Of special interest were numerous original photographs, some by Zeeman himself, and others by his pupils, which highlighted the history of the Zeeman effect.

The technical papers in pure and applied spectroscopy included the following: "Some Remaining Problems in the Analysis of Spectra" by A. G. Shenstone of Princeton; "Zeeman Effect and Hyperfine Structure" by D. C. Jackson of Oxford; "The Convection of Light under Different Circumstances, with Special Reference to Zeeman's Experiments" by Zernike of Groningen; "Spectra of Highly Ionized Atoms" by B. Edlén of Lund; "Determination of Temperature from Spectra" by J. A. Smit of Utrecht; "Spectroscopy of the Higher Atmosphere" by L. Vegard of Oslo; "Radiofrequency Spectroscopy" by B. Bleaney of Oxford; "Atomic Spectra in Solids and Solution" by L. J. F. Broer; "The Problem of the Luminescence of Sodium in the Upper Atmosphere" by A. Kastler of Paris; "Experimental Attainment of Very Long series in the Spectra of the Alkali Atoms" by J. E. Mack of Madison; "Methods of Analysis in the Spectra of the Rare Earths and in the Very Complex Spectra of Thorium and Uranium" by P. Schuurmans of Amsterdam; "The Forbidden Lines of He and their Zeeman Effect" by P. Jacquinot of Paris; "The Energies of a Compressed H Atom" by S. R. deGroot of Amsterdam; "Electric Depolarization of the Zeeman Effect" by P. A. F. Klinkenberg; "The Intensity Efficiency of the Fabry-Pérot Interferometer" and "Multiple Beam Interference Examination of the Topography of a Diamond Crystal" by S. Tolansky of England; "Testing of Planeness of Interferometer Plates" by E. Rasmussen of Copenhagen.

An interesting feature of the Congress was the amount of time devoted to astrophysical applications. One full day was devoted to astro-

nomical lectures on "The Solar Spectrum and the Model of the Solar Atmosphere" by B. Strömgren of Copenhagen; "The Opacity of the Solar Atmosphere and the Negative Hydrogen Ion" by D. Chalonge of Paris; "The Constitution of Giant Stars" by D. H. Menzel of Harvard; "The Effect of Diluted Radiation in Astronomical Spectra" by O. Struve of Yerkes; "Line Spectra of Delta Cephei" by A. Pannekoek of Amsterdam. The two astronomical sessions were presided over by J. H. Oort of Leiden and J. Houtgast of Utrecht, respectively. It is expected that all papers of the Congress will be published in a memorial volume. The first two papers highlighted the importance of the continuous absorption produced by the negative hydrogen ion—a particle which consists of an ordinary hydrogen atom, to which an extra electron has stuck. Strömgren has made numerous computations of the structure of the solar atmosphere and of its absorption in different spectral lines. These absorptions depend not only upon the monochromatic action of the particular species of atom, but also upon the continuous absorption of the entire atmosphere. Chalonge and Barbier have obtained new and significant confirmations of the continuous absorption of negative hydrogen in the spectrum of the sun and other main sequence stars. Some of their results depend upon observations just completed on the Jungfraujoch in Switzerland. Among other things, they find a marked "jump" at the Balmer limit of the solar spectrum, a result which differs from that of previous workers.

If it is at all possible to generalize, we might say that these two papers demonstrated the enormous progress which has been made in the interpretation of the spectra of ordinary main-sequence stars, and suggested interesting excursions for future research, such as Strömgren's idea that the mechanism of "pure absorption" plays a much more important rôle than had previously been considered probable, or Chalonge's hint that perhaps some relatively small further source of continuous opacity should be looked for in order to bring Chandrasekhar's theoretical results into complete accord with the observations. In this connection the audience was interested to see several lantern slides sent by Dr. Chandrasekhar especially for the congress, in which he had illustrated his own and Dr. Munch's latest results concerning H^-. As Strömgren has pointed out our knowledge of the physical properties of the solar atmosphere on the one hand, and of the continuous and monochromatic absorption coefficients of the atoms on the other, enables us to predict the contours of the stronger lines, in excellent agreement with the observations.

The other three astronomical papers, though devoted to three entirely different subjects, had one thing in common: they constituted a vigorous attack upon the conventional theories of giant and super-giant atmospheres. It is interesting to note that these attacks originated in a paper published by Professor Pannekoek several years ago which has

received much less attention than it deserves. In this paper he had shown that the surface gravity of a supergiant, like α Cygni, inferred from the Stark effect of the H lines, is of an entirely different order of magnitude from that inferred from the estimated masses and radii of these stars. In their new work Pannekoek and Walraven have determined the pressures in δ Cephi by means of the ionization theory, and have found discrepancies from the usual pulsation theory which they attributed to a "shell" phenomenon. Menzel goes even further and attempts to create an entirely new model for a giant star—one in which the filamentary structure of the prominences plays an important rôle. He suggested that a normal giant may have a hot Wolf-Rayet core and a greatly extended, filamentary atmosphere supported against gravity by the motions of large numbers of formations similar in character to the solar prominences. Finally, in my own paper, attention is directed towards the similarity, in many respects, between the spectra of typical shells, like that of Pleione, and those of normal supergiants, like α Cygni. For example, in the case of Pleione the spectrum was at one time that of a fairly normal main-sequence B star. Since 1938 a shell has been formed around the B star, and its present spectrum, though anomalous, can be best described as that of a supergiant F star. At the same time its apparent magnitude has not changed greatly. We have no recent measures of the color index, but tentatively we can think of Pleione with its greatly extended shell as having increased its diameter to balance its reduced flux of radiant energy per unit surface.

Another forenoon was devoted to the inspection of the Astronomical Institute of the University of Amsterdam under its new director, Professor H. Zanstra, and his eminent predecessor, Professor A. Pannekoek. Several shorter papers were also presented by M. Waldmeier on his observations of the solar corona at Arosa, Switzerland, by H. Van der Linden on photometric measurements in star-clusters at Ghent, Belgium, and by V. Migeotte on his remarkable extension of the infrared spectrum of the sun.

The astronomical papers of the congress contained little or no mention of the Zeeman effect, and it must be regretted that there was no contribution from one of the large solar observatories where the Zeeman effect is perhaps the most important single tool. In stellar spectroscopy there has as yet been no occasion to introduce the Zeeman effect, but there is no reason why it should not be possible to detect the magnetic broadening of spectral lines with instruments like the powerful Coudé spectrographs at Mount Wilson or at McDonald. Such a broadening may be present in rapidly-rotating stars because of the general magnetic fields that may be expected in such stars; or it may be present as a result of excessive "sun-spot" activity, with each spot

serving as a magnetic dipole.*

As a small international meeting of astronomers the occasion was a great success. The presence of a strong delegation from Great Britain, with E. A. Milne, H. H. Plaskett, F. J. M. Stratton, and J. A. Carroll, added greatly to the interest of the discussions. Some of the papers on pure physics were of considerable astronomical importance, as for example the description of the Utrecht program of accurate intensity measurements of spectral lines. It is more doubtful that the physicists obtained much of value from the astronomers. With a few notable exceptions there was not in evidence any great desire on their part to help with the solution of astronomical problems. Perhaps this was caused by fatigue and preoccupation with their own immediate tasks.

An interesting point was brought out by Professor Gorter in his concluding remarks. Spectroscopy has ceased to be the youngest and most rapidly growing off-shoot of physics. Fifty years ago, and even twenty years ago, it was the most exciting field of study, and all the young physicists who wanted to be "modern" went into spectroscopy. However, in more recent years it has become a "mature" and fully developed discipline and has taken a respected place among other, still earlier, branches, such as electricity and magnetism, or heat. A recognition and evaluation of this fact is important to astronomers. There are now relatively few physicists left who are engaged in the study of spectroscopy. Yet, there are many important problems which must be solved if astrophysics is to advance. The theoretical and experimental determination of transition probabilities in atomic and molecular spectra, the structure of those molecular spectra which are present in late-type stars, in comets and in planetary atmospheres, the peculiar absorption phenomena of small particles in interstellar space, the processes of collisions between atoms and other particles, are only a few of these tasks. Since it is unlikely that many physicists will have the time to study these problems, it is important that our astrophysical institutions should train the necessary theoretical and practical workers who could undertake this work.

The meeting ended with a special session of the Amsterdam Academy of Sciences, to which some of the delegates were invited as the guests of Professor J. Clay, the director of Amsterdam's physical laboratory. Professor D. H. Menzel of Harvard earned the enthusiastic applause of the members of the Academy for the demonstration of his new and spectacular motion picture film of solar prominences observed at Climax.

*The Zeeman effect in rapidly-rotating stars has since been discovered by H. W. Babcock (*Ap J.*, **105**, 105, 1947).

Tercentenary of John Flamsteed (1646-1719)*

By SIR HAROLD SPENCER JONES, F.R.S.†

Today, August 18, we commemorate the tercentenary of the birth of John Flamsteed, the first Astronomer Royal and one of the greatest practical astronomers of this day. I am glad to have the opportunity to pay a tribute to the first of my predecessors, who labored with single-minded devotion at Greenwich for forty-four years. It is appropriate that this commemoration should be held in this church: for Flamsteed held the living of Burstow for thirty-five years, he paid frequent visits here, and in the chancel of this church he lies buried.

John Flamsteed was born at the village of Denby, several miles northward from Derby, on August 19, 1646. His parents were, in his own words, "of known integrity, honesty, and fortune, as they were of equal extraction and ingenuity." When barely three years old he lost his mother, his father being left with the care of a daughter, then not a month old, and of John, who was a child of a weakly constitution. He was educated at the free school of Derby, where his father lived. At the age of fourteen, he contracted severe rheumatic trouble, as a result of river-side bathing. The effects of this he felt throughout his life; he suffered from perpetual ill-health, "my distemper" as he called it. He became so weak that he was scarcely able to go to school and, when not quite sixteen years old, he left school for good. At school his studies had consisted largely of history and Latin. Being lent a copy of Sacrobosco's "Spheres" in Latin he soon began to show an inclination towards mathematics and astronomy, while his father taught him arithmetic. He observed and recorded an eclipse of the sun and learned how to predict eclipses and to calculate the places of the sun. His practical inclinations were shown in the construction of dials and of a quadrant and in grinding lenses for telescopes.

Self-taught by dint of assiduous reading and study, Flamsteed acquired a wide knowledge of astronomy. His observations, made with a small telescope, showed him how deficient were the current astronomical tables. In 1669 he calculated some occultations of stars by the moon for the year 1670, which were transmitted by a friend to Lord Brouncker, the president of the Royal Society. This brought Flamsteed into communication with Oldenburg, the secretary of the Society, and with John Collins, a fellow of the Society, who maintained an extensive correspondence with Newton, Gregory, and other prominent fellows.

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*An address delivered at a tercentenary service held in Burstow Parish Church in England on Sunday, August 18, 1946. Printed also in *Nature*, **158**, 290 (August 31, 1946).

†Astronomer Royal.

In 1670 Flamsteed, at his father's suggestion, went to London to become personally acquainted with his learned correspondents. He visited Oldenburg and Collins, who took him to the Tower to meet Sir Jonas Moore, the Surveyor-General of the Ordnance, a mathematician and a fellow of the Royal Society. This was an important event in Flamsteed's life, for Sir Jonas Moore took a great interest in the young astronomer, and became his warm friend and patron: to his help and encouragement Flamsteed owed a great deal. Later in 1670 Flamsteed entered himself at Jesus College, Cambridge, and in 1674 he took the M.A. degree. While in Cambridge he made the acquaintance of Dr. Barrow and Mr. Newton.

Flamsteed spent some part of his time in astrological studies, as was not uncommon at that time. But in 1673, he wrote an ephemeris wherein he "showed the falsity of astrology and the ignorance of those who pretended to it." At Sir Jonas Moore's suggestion, he prepared an account of the tides for King Charles II. He also constructed a barometer (a "weather glass" as he called it) and afterwards gave one to Sir Jonas Moore; he, in turn, presented weather glasses to the King and the Duke of York, giving them also the directions which Flamsteed had prepared for judging the weather from their rise or fall. This, Flamsteed records, brought him "more than ordinary regards from them."

Sir Jonas Moore had shown his interest in Flamsteed in a practical way by offering to pay £10 a year and to obtain a further £10 from two friends, for the employment of an assistant to help him with his observations and computations. On taking his degree, Flamsteed designed to take orders and to settle in a small living near Derby, which was in the gift of a friend of his father. From his early years he had been of a very pious and religious turn of mind. In 1675 he took orders at Ely House, at the hands of Bishop Gunning.

Flamsteed, in the account of his life, says "My desires have always been for learning and divinity; and although I have been accidentally put from it by God's providence, yet I have always thought myself more qualified for it than for any other employment; because my bodily weakness will not permit me action and my mind has always been fitted for the contemplation of God and his works."

Plans were at this time under discussion for founding an observatory in London, under the auspices of the Royal Society. Sir Jonas Moore was greatly interested in this project and invited Flamsteed to London to consult him on the subject. He resided at Sir Jonas Moore's house in the Tower, where he carried on his astronomical observations. But while this scheme was under consideration, the event happened which definitely turned Flamsteed's life into a new direction.

At this time there was no satisfactory method of finding the longitude of a ship at sea. The need for a reliable method had become urgent. The proposal had been made that the longitude should be form-

ed by comparing the position of the moon (got by observing her distance from the fixed stars) with her places given by astronomical tables. A Commission, which included Lord Brouncker, the principal officer at the Navy Board, Sir Jonas Moore, and Flamsteed, was set up to report on the plan. The Commission reported (Flamsteed tells us) that this method was indeed the most likely to prove useful to our sailors because most practicable; but that the catalog of fixed stars was both erroneous and incomplete; that the best tables of the moon's motions were inaccurate; and that these errors would sometimes cause an error of three hundred leagues in the determination of the longitude; so that our sailors could expect no help from this method till both the places of the fixed stars were rectified and new tables of the moon's motion made, that might represent her place in the heavens to some tolerable degree of exactness; for which a large stock of very accurate observations, continued for some years, was altogether requisite, but wanting. That therefore His Majesty would give a great and altogether necessary encouragement to our navigation and commerce (the strength and wealth of our nation) if he would cause an observatory to be built, furnished with proper instruments, and persons skillful in mathematics, especially astronomy, to be employed in it, to take new observations of the heavens, both of the fixed stars and planets, in order to correct their places and motions, the moon's especially; that so no help might be wanting to our sailors for correcting their sea charts, or finding the places of their ships at sea.

When the report was shown to the King, he was startled at the assertions of the fixed stars' places being false in the catalog, and said, with some vehemence, "He must have them anew observed, examined and corrected, for the use of his seamen," and further, when it was urged to him how necessary it was to have a good stock of observations taken for correcting the motions of the moon and planets, with the same earnestness, "he must have it done." And when he was asked who could, or who should, do it? "The person (says he) that informs you of them." The outcome was that Charles II decided to found an observatory and Flamsteed was appointed to take charge of it. Chelsea and Hyde Park were considered as possible sites, but in the end, at the suggestion of Sir Christopher Wren, Greenwich was chosen, Charles II giving a site on the highest ground in the Royal Park at Greenwich. Wren was appointed architect of the observatory, which was built at a cost of £520, defrayed by the sale of old and decayed gunpowder. The foundations were laid in August, 1675, and the building was completed by July, 1676. Flamsteed was appointed, in the terms of the Royal Warrant, "our astronomical observator" (the designation Astronomer Royal was given at a later date: Flamsteed usually signed his name as M.R.—Mathematicus Regius).

He was granted an allowance of £100 a year; from which £10 was

deducted as tax. Inadequate as this was, it was often in arrears. Although the Committee had recommended that the observatory should be provided with proper instruments and with skilled persons to observe with them, no instruments were, in fact, ever provided by the Government and the only assistance given was that of a common laborer. Flamsteed's patron, Sir Jonas Moore, generously presented him with a large iron sextant and two clocks by Tompion, the most celebrated maker of clocks of the day. He borrowed also a small quadrant from the Royal Society, but, on the death of Sir Jonas Moore, this was called back.

With the sextant it was possible to observe only the relative positions of the stars. An instrument fixed in the meridian was required to determine their absolute positions. Until such an instrument was provided it was not possible for him to achieve the practical ends for which the observatory had been established. Flamsteed made repeated applications to the Government for a mural arc; it was often promised but it never came. In 1681 he therefore had a mural arc made at his own expense, but it proved to be not sufficiently rigid in construction, and the observations made with it were not of the accuracy that was needed. In 1684 Lord Keeper North presented him with the living of Burstow; soon afterwards his father died and Flamsteed, finding his income somewhat increased, decided to construct a new mural arc, much stronger than the former. This was completed in 1689, at a cost of upwards of £120. The Master of the Ordnance had promised that the cost should be repaid to him; but the promise was not kept and not a farthing of the money he had expended was ever refunded to him.

The tasks that Flamsteed had undertaken were Herculean. They were, first, the construction of a catalog of the fixed stars, more extensive and more precise than all existing ones; secondly, the systematic observation of the sun, moon, and planets with the view to revising the theories of their apparent motions and to constructing tables from which their positions could be computed with the desired accuracy. These tasks were far beyond the capacity of one man, for they involved not merely continuity and regularity of observation over many years, but also extensive computations. It was essential for Flamsteed to have assistance; as none was provided by the Government, he had to defray the cost out of his own pocket. To meet his expenses, it then became necessary for him to take private pupils for instruction in mathematics and astronomy. An additional burden was put upon him by the King who ordered him to instruct two boys monthly from Christ Church Hospital in mathematics. These calls on his time necessarily distracted him from carrying on his astronomical observations with the expedition that he desired. In 1710 Flamsteed stated that he had spent upwards of £2,000 above his salary in furnishing instruments and in hiring assistants and computers.

Under such disheartening conditions and with his persistent ill-health, it was surprising that Flamsteed was able to accomplish so much. His observations were planned with a careful attention to accuracy in their most minute details; he introduced new methods into practical astronomy, many of which are in use today; an immense mass of computations were carried out in a systematic and orderly manner, to correct the theories and to improve the tables of the sun, moon, and planets, and to elucidate intricate points in practice and theory. He established the fundamental essentials of practical astronomy on sure foundations, which served as a landmark for his successors. In accuracy his observations far exceeded those of his predecessors or contemporaries; they are, in fact, the earliest observations from which the phenomenon of aberration is clearly deducible. In addition he maintained an extensive correspondence with the principal astronomers and scientists of his day.

Flamsteed had realized more clearly than any of his contemporaries that a large stock of accurate observations, continued for many years, was needed to accomplish the tasks on which he was engaged. But it was not long before demands began to be pressed upon him for the publication of his results.

These demands Flamsteed resisted, claiming the right to decide for himself when his results were sufficiently complete and accurate to justify publication. This question of publication was to involve Flamsteed in acute controversies with Newton and Halley, which embittered the later years of his life. For some years Flamsteed and Newton manitained a friendly correspondence and Newton often visited the observatory. Flamsteed had a high regard for Newton; he said that "Mr. Newton's approbation is more to me than the cry of all the ignorant in the world." Newton was occupied at this time with the theory of the motions of the moon; he made frequent requests for Flamsteed's observations and at various times asked him to make observations at certain specified periods. Flamsteed complied with all these requests; he seems, however, to have resented that Newton "was too inconsiderate as to presume he had a right to that which was only a courtesy" and that "he said not one word of his obligations or debt to the Royal Observatory." The relations between the two men gradually became cooler and eventually widened into an open breach.

At length Flamsteed began to consider the question of publication of his observations and of his great catalog of stars. He planned to bring out a single great work, which would be a monument to his industry and skill, and would raise the name of England in the astronomical and scientific world. He prepared an estimate of the number of pages; but at this juncture, Prince George, consort of Queen Anne, having learnt of Flamsteed's labors, proposed to have the work printed at his own expense. A body of referees which included Newton, then president of the Royal Society, was appointed to inspect Flamsteed's papers; this

was done, and it was recommended that all should be printed. Flamsteed was instructed to hand over a copy of his observations and of his catalog; but as the catalog was incomplete and imperfect, he deposited a sealed copy, not for printing but as a guarantee of furnishing a revised and completed copy at a future date. The printing proceeded very slowly and the first volume alone had been completed by 1708, when Prince George died. In 1711 the printing was resumed by order of Queen Anne, but unknown to Flamsteed; a garbled and incorrect edition of the observations with the mural arc and of the imperfect and incomplete catalog, which had been deposited under seal, was published in 1712 without Flamsteed's consent. It is not surprising that this unauthorized publication was deeply resented by Flamsteed.

A further source of trouble to Flamsteed was the appointment in 1710 of a Board of Visitors of the Observatory with power to demand from Flamsteed each year a true and fair copy of his observations. For Flamsteed, not without reason, looked upon the observations as his own property. It must be remembered that the instruments with which they were made were his own; "the very books in which these observations were entered, the pens and the ink with which they were written, the paper on which they were copied, were all furnished at his own cost, and not at the expense of the public, who contributed nothing but his paltry salary." This question of the proprietorship of the observations made at the Royal Observatory came up in 1762, on the death of Bradley, the third Astronomer Royal. Bradley's executors took possession of his observations and maintained their right to them in a lengthy lawsuit brought by the Crown, even though Bradley was supplied with instruments of the best sort at the public expense and, moreover, had an addition of £250 per annum to his salary. With how much greater right did Flamsteed then regard his observations as his own property!

Flamsteed resolved to publish a correct version of his observations and of his catalog at his own expense. With this end in view he applied to Newton for the return of the manuscript copy of the catalog and of 175 sheets of observations. Being unable to secure them he was compelled to recopy them all for the press at an expense of nearly £200.

Whilst engaged on this work Queen Anne died, there was a change of ministry, and people more friendly to Flamsteed came into power. He was able to secure three hundred out of the four hundred copies of the garbled and incorrect volume that had been printed and he publicly burnt them "as a sacrifice to heavenly truth." He then began printing a revised edition at his own expense, but he did not live to finish the task. In 1719 he died before the printing was nearly completed. It was finished and published in 1725 by the devoted labors of Crosthwait and Sharp, who had been Flamsteed's private assistants.

The "Historia Coelestis Britannica," in three volumes, containing Flamsteed's observations and his great catalog of nearly three thousand

stars, was the first important contribution to science given by Greenwich Observatory to the world. It opened a new era in sidereal astronomy and stands as an enduring monument to Flamsteed's scrupulous care and unflagging industry and to what he was able to achieve in his forty-four years at the Royal Observatory, in the face of official neglect and very great difficulties. The injustice with which Flamsteed had been treated in his life did not end at his death. The Office of Ordnance attempted to prevent his executors from removing his instruments from the observatory and brought a lawsuit against them; but, as the executors were able to prove that the Office had never paid for any of the instruments, nor even for their repair, the case could not be sustained.

Flamsteed was a man of singular piety; his diaries and letters abound with devout expressions of thankfulness to God. Suffering from continual ill-health, denied the official support which he was entitled to expect, unjustly treated by those who did not appreciate the difficulties with which he had to contend, it is not to be wondered at that in his later years he became embittered. His unwearied perseverance in the face of difficulties and his single-minded devotion to his duties laid the foundations upon which the pre-eminence of the Royal Observatory among the institutions devoted to practical astronomy has been built. He realized better than any of his contemporaries what was most needed in his day for the promotion of astronomy. His work was marked by no brilliant discoveries; but, by unflagging industry and scrupulous care, by systematic observations and insistence upon accuracy, he bequeathed to his successors an immense treasure of observations. His name will always be honoured as that of the first great British observer who established precise astronomy upon secure foundations, and is enrolled among those who have made permanent contributions to the advancement of astronomy.

Life and Work at the Lick Observatory*

By JULIE M. VINTER HANSEN

The Lick Observatory owes its existence to the American millionaire James Lick, a piano-maker from Pennsylvania, who in his later years settled down in San Francisco and became rich through investments in land. He decided that his money should be devoted to public uses such as statuary, Free Baths, a Home for Old Ladies, a California Institute of Mechanic Arts (a manual-training school for boys and girls), all in San Francisco, but the largest amount, $700,000, should go to the building of an astronomical observatory, to be known as the Lick Ob-

*Translation in part of a paper published in *Nordisk Astronomisk Tidsskrift*, 1946, No. 2, made by the author at the request of the Editor of POPULAR ASTRONOMY.

servatory, which should house the most powerful telescope of the world, and which, after its construction, should be given to the University of California. As far as is known James Lick took no special interest in astronomy but perhaps he thought, and rightly so, that he could erect a lasting monument for himself by having his name connected with such an institution. As the site of the Observatory, James Lick himself, in 1875, selected Mount Hamilton, a mountain ridge in Santa Clara County 70 miles southeast of San Francisco at an altitude of about 4200 feet. It was stipulated that the County should build a good road to the summit, a condition which the County promptly fulfilled. James Lick died in 1876, not having had the pleasure of seeing the Observatory completed. He was later entombed in the base of the column that carries the big refractor.

The year 1888 saw the Observatory ready for work. The main instrument was a 36-inch refractor, the objective lens made by Alvan Clark. Its magnifying power covers the range 270-3000. Although it is no longer the largest telescope in the world, it is still an excellent instrument and belongs among the most effective of all existing large telescopes. When it was built, astronomical photography was still in its infancy and at first the refractor was used mainly for visual observations, but now most of the work is done photographically. The telescope is now equipped with a very satisfactory electrical drive. The beautiful, harmonious dome has a movable floor, the first of its kind to be constructed. The floor has a diameter of 60 feet and it can be raised or lowered through 16½ feet, which of course makes observations with this large instrument quite comfortable. In the course of time various auxiliary instruments for the refractor were acquired; for instance, spectrographs with one, two, or three prisms of which the very effective Mills 3-prism spectrograph should be particularly mentioned; also an instrument, designed by H. M. Jeffers, for automatic photography of a series of pictures of a visual binary on a single plate, and a very delicate photoelectric photometer, made by G. Kron, with both red- and violet-sensitive cells.

Besides this main instrument the Observatory from the start was equipped with a 12-inch equatorial refractor and a 6½-inch meridian circle, both objectives made by Alvan Clark. Later on the Observatory acquired various larger and smaller instruments among which must be mentioned first of all a 36¼-inch reflector with a mirror constructed by Sir Howard Grubb. This telescope was a gift, in 1895, from the Englishman, Edward Crossley. The transportation of the instrument and its dome from England was made possible through subscriptions from citizens of California. In recent times the Observatory has received a fine gift of a 20-inch double astrographic telescope (focal length 12 feet) from the Carnegie Corporation. As yet only the tube carrying the photographic lens, designed by Frank Ross, is in use, while

the photovisual lens has not been completed.

Furthermore the Observatory owns photometers, a microphotometer, instruments of various construction for the measurement of plates, chronographs, clocks, among them a Riefler and a Shortt clock, computing machines, sensitive seismographs, to whose acquisition the newspaper king, Hearst, has contributed. The Observatory also owns an excellent library of about 20,000 books. The spacious, airy offices of the

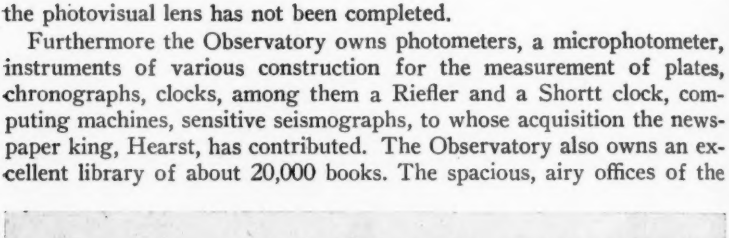

FIGURE 1

The Lick Observatory from the East. On the Eastern ridge are scattered residences of the staff and the work shops. The dome of the double astrograph is seen, and behind that the dormitory of the unmarried astronomers, and on the summit the main building with the dome of the 36-inch refractor. Far to the left the Crossley dome may be espied.

astronomers are practically all situated in the main building and are favored with a beautiful view of the surrounding mountains and valleys. The Observatory employs a professional photographer who has his own photographic laboratory and who develops the exposed plates and makes the eventual enlargements of the beautiful photographs of celestial objects which now and then are issued by the Observatory. The institution also has its own mechanical work-shops both for metalwork and carpentering, complete with instrument-maker, cabinet-maker, carpenter, and electrician. It also has its own water supply from two mountain springs.

The choice of Mt. Hamilton as the site of the Observatory has proved very satisfactory. The air is quiet and free from dust so that the stellar images are well defined, and in consecutive long periods, particularly in summer, the sky is perfectly cloudless. An August night on Mt. Hamilton when the Milky Way with the magnificent part around Scorpius and Sagittarius stands nearly vertical to the horizon is an unforgettable experience for an astronomer, particularly for one who is accustomed to a country with a very temperamental climate. The Observatory is situated on its own extensive grounds of 3100 acres, all uninhabited, of sparsely wooded mountain land where are met only deer, skunks, squirrels, roaming astronomers, coyotes, an occasional mountain lion, a few horses, and, in summer time, rattle snakes, while the big, black

buzzards sail high in the air on the outlook for a little food. The nearest little town, San José, with about 67,000 inhabitants, is 13½ miles away as the crow flies, and the Observatory is therefore only to a very slight degree bothered by city lights.

The excellent location combined with the favorable weather conditions and the good instrumental equipment makes it possible to plan extensive, systematic observational programs and, what is still more important, makes it possible to carry them through. Early in the history of the Observatory a systematic investigation was started of all stars down to the 9th magnitude in that part of the sky which can be observed with sufficient accuracy from Mt. Hamilton with the purpose of determining the ratio between the number of visual double stars and that of single stars. During this work, with which particularly the name of Robert Grant Aitken is connected, more than 4800 new, close, visual double stars were discovered, and it was found that on the average every eighteenth was a double star and that the ratio between the two sorts of stars is greater in the Milky Way than in other regions. Aitken who for a few years was director of the Lick Observatory has published a catalogue[1] in which are listed 17,180 double stars and which is a continuation and supplement of Burnham's well-known Double Star Catalogue. The observation of double stars, both visually and photographically is still continued at the Lick Observatory, mainly by H. M. Jeffers.

The largest systematic program that has been made and is still in progress at the Observatory is no doubt the measurement of stellar radial velocities. Particularly the names of W. W. Campbell and J. H. Moore are known in connection with this large program, but many others, such as F. Neubauer, have also made valuable contributions and practically everybody who for some time has worked at the Observatory has taken a part in this work either in the taking of the plates or in their measurement. The work was started in 1896 and more than 26,000 spectrograms of about 3,000 of the brighter stars have been obtained in the course of time. The program includes not only stars visible from Mt. Hamilton but also more southern stars observed from a branch observatory in Santiago, Chile, which functioned in the years 1903-29. Through this work important contributions have been made towards the solution of the problems of the motion of our solar system among the stars and of the motions of the stars in our galaxy. The observations are made with the 36-inch refractor, generally in connection with the Mills 3-prism spectrograph. Much of the work is pure routine, but great care must be taken to avoid observational errors. During the observations when the drive has been regulated in such a way that the star slowly moves along the slit to give the spectrum width the observer, using the slow motion, must bring the star back onto the slit whenever

[1] "New General Catalogue of Double Stars within 120° of the North Pole," 1932.

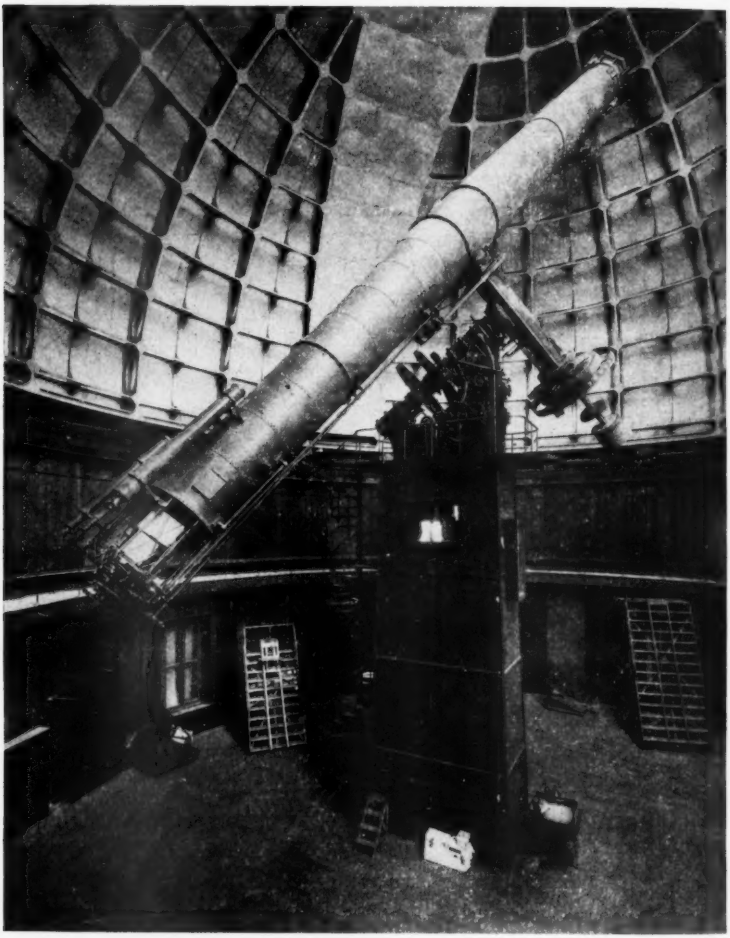

FIGURE 2
THE 36-INCH REFRACTOR

it is about to disappear from the field, and he must also keep an eye on the thermostat of the spectrograph, because the instrument has to be kept at a constant temperature during the exposure of the plate. The measurement of the spectral lines of the star relative to the lines of a comparison spectrum (of iron or titanium) which has been photographed on the plate on both sides of the stellar spectrum is made in either an ordinary measuring machine or in a spectro-comparator. In

this latter case the displacement of the lines is measured in relation to a standard spectrum, for instance of α Bootis in the case of redder stars or of the reflected solar spectrum for more yellow stars. Such a standard plate has of course been measured very accurately by various observers before it is used as a comparison plate.

While such measurements are performed the discovery is sometimes made that some star has a variable radial velocity. This may be caused by pulsations in the star, which was the case with Polaris whose variable radial velocity was discovered in 1899. The period is 3.97 days and Hertzsprung later showed that the star is of the δ Cephei type. But in most cases the variable radial velocity is due to the fact that the star is a component in a spectroscopic binary. As soon as a star has shown variations in radial velocity it is placed on a special list and is observed much more frequently than the stars on the ordinary program. Over 400 spectroscopic binaries have been discovered during the investigations on Mt. Hamilton and at its southern station. Combined with similar discoveries at other observatories and with the great number of known visual double stars the conclusion has been reached that the incidence of double stars is very frequent, and that probably ¼, perhaps even ⅓, of all stars are members of a double or a multiple system. It is well known that it is possible to deduce the orbit of a spectroscopic binary from the curve of the radial velocity, which curve shows the relation between this velocity and the time of observation. All the elements cannot be had, however, for the semi-major axis, a, and the inclination, i, are found only in the combination $a \sin i$. Ordinarily it is possible to observe the spectral lines of only the brighter component, but in some cases both spectra are seen, and those are joyful occasions for then the mass ratio of the two components can be computed. In the simplest case when the components are of about the same spectral class the lines will be seen periodically double, but it is far from always that it is as easy as that to get hold of the spectrum of the second component. In a binary, 31 Cygni, investigated by the author, the primary is a red supergiant, while the fainter component is a white B star that shows its existence by veiling the lines of the primary but does not produce any measurable lines in that region of the spectrum which is photographed with the Mills spectrograph, whose central line is around λ 4500. An observatory of the rank of the Lick Observatory resorts, however, to many auxiliary means and after several attempts Dr. Moore succeeded in building a light-flint one-prism spectrograph, equipped with a 12-inch camera, which apparatus was affixed to the 36-inch refractor and with which it proved possible, with exposures up to 2½ hours, to photograph a spectrum of the white star with a few measurable lines farther out in the violet region than could be reached with the Mills spectrograph. In this way an evaluation of the mass ratio of the two stars was attained, namely 1.7.

To the 36-inch refractor can also be attached the afore-mentioned sensitive photoelectric photometer constructed by G. Kron, who, together with Mrs. Kron, has made long series of observations of eclipsing binaries.

With the other main instrument, the Crossley reflector, a series of photographs of planetary and irregular nebulae has been made and studies of these photographs have given valuable information about

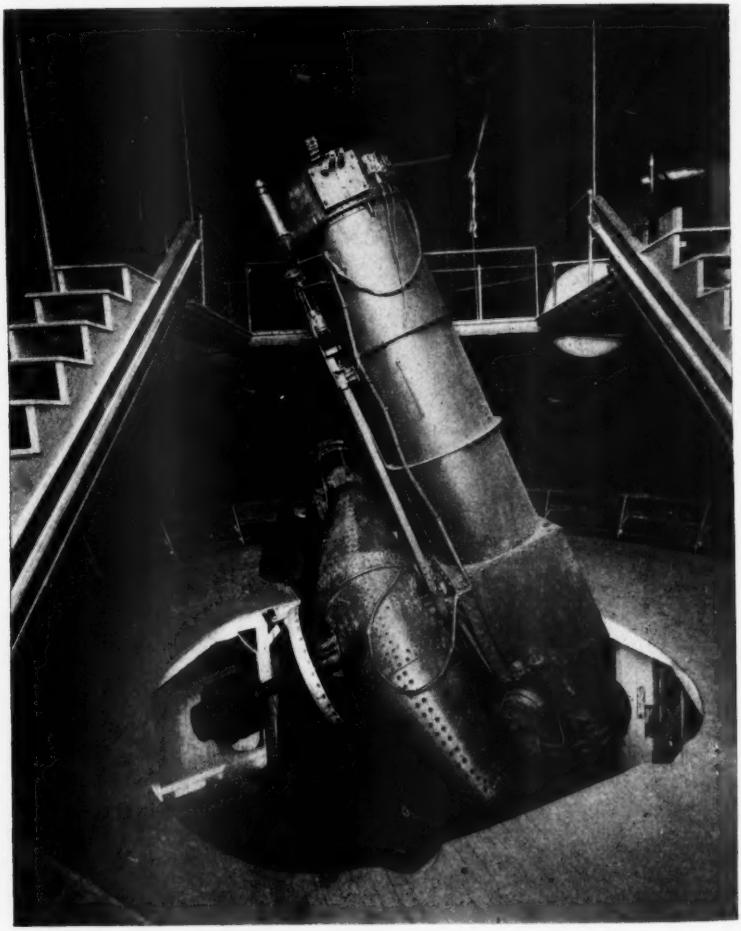

FIGURE 3
THE CROSSLEY REFLECTOR

the structure of these gaseous objects. In conjunction with the instrument a slitless quartz spectrograph can be used, particularly for the study of these nebulae, and together with spectrograms of the same objects obtained at the 36-inch refractor with three- and one-prism spectrographs these investigations have greatly added to our knowledge of the internal motions of these objects and of their motions in space. It seems that the planetary nebulae move in space with far larger speeds than the ordinary stars. The names of Curtis, Campbell, Moore, Wilson, and Wright are connected with this extensive study of gaseous nebulae.

The Crossley reflector has also been used for the investigation of globular clusters and of distant galaxies, and hundreds of new faint spirals and elliptic nebulae have been discovered on the Crossley photographs. The beautiful pictures of the brighter spirals lend themselves admirably to the study of the structure of these objects. N. U. Mayall has determined radial velocities for a number of globular clusters and is continuing the investigation of anagalactic nebulae.

Studies of open clusters, like the Pleiades, have also been made at Mt. Hamilton both with the Crossley reflector and the 36-inch refractor, and this work is still in progress. The stars in the clusters are observed as regards magnitude, spectral class, radial velocity, and proper motion from which data deductions may be made as to the dimensions of our stellar system and the existence of interstellar material. R. Trumpler has made great contributions to this work.

The excellent climatic conditions on Mt. Hamilton make possible extensive studies of the surfaces of objects inside our own solar system, and both main instruments have been used to secure photographs of the major planets, particularly Venus, Mars, Jupiter, and Saturn, in light of different colors from the infrared to the ultraviolet, and this has added to our knowledge of the atmospheric conditions and the structure of the surfaces of these objects. In 1909 an expedition was sent to the highest mountain in California, Mt. Whitney, to supplement the observations hitherto obtained of the atmosphere of Mars, and it could be shown that very little water vapor and oxygen are found in that atmosphere, a result later confirmed elsewhere.

In the earliest days of the Observatory the sun was photographed every clear day but this work was stopped when the Mt. Wilson Observatory came into existence. On fifteen occasions of solar eclipses the Lick Observatory sent out expeditions to places all over the world and only four were hampered by bad weather. The expeditions were particularly interested in studies of the corona and in the deflection of light, predicted by Einstein, when it passes through the gravitational field of the sun. At the eclipse of 1922 when the Lick Observatory was stationed in Australia it was successful in observing this deflection with far greater accuracy than had been done previously. The deflection

was measured to be 1″.72, while the theoretical value is 1″.745.

Long series of observations have been obtained at the meridian circle, particularly by Tucker, but this work is now discontinued.

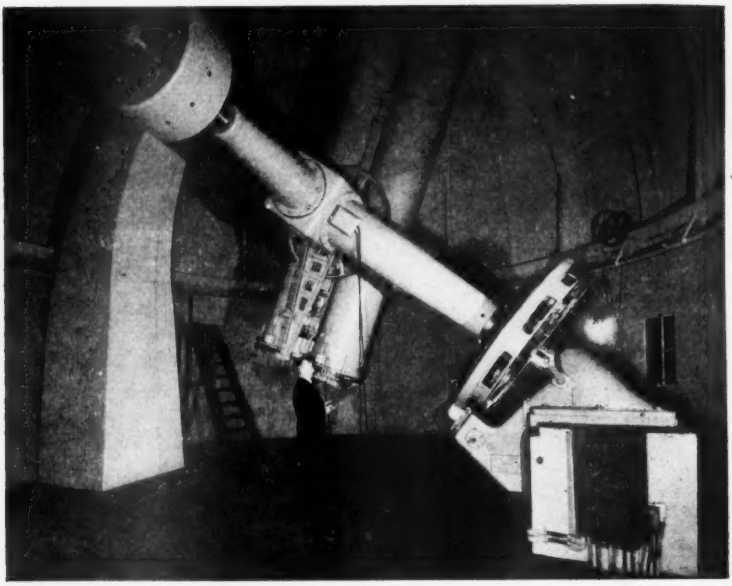

FIGURE 4
THE DOUBLE ASTROGRAPH

The 20-inch double astrograph, for whose construction the honor goes to W. H. Wright, is yet so new that there has not been time to carry through an extensive program, but a couple of series of observations of the asteroid Eros have been obtained, and a rather ambitious program is planned, namely the photographing of the entire accessible part of the sky for the purpose of establishing a new fundamental system using the anagalactic nebulae. One of the important problems of stellar astronomy is the determination of stellar motions inside our own galaxy and for this we need a good system of reference. Much time and care have been spent to produce reliable Fundamental Catalogues. Of such catalogues two may be mentioned: Auwers' "Neuer Fundamentalkatalog" and Boss' "Preliminary General Catalogue," called, respectively, N.F.K. and P.G.C. Both have recently been revised, and especially as regards the Boss catalogue, enlarged. Fundamental catalogues come into being by critical revision and comparison of star positions, old and new. For such work it is necessary to know the constant of

precession and the proper motions of the stars. If the constant of precession is changed the values of the proper motions will also change and this constitutes one of the great difficulties which confront the makers of fundamental catalogues. If we had an accurate knowledge of the mechanics that govern the motions of the stars we would have surmounted this difficulty but we have not yet reached this point. It would be ideal if we could determine a system of reference independent of the stars in the Fundamental Catalogues and theoretically this should be possible using the motions of the planets according to Newton's law. This procedure is kept in mind and a number of asteroids have been selected which are particularly adaptable for such use,[1] but as long, systematic, and accurate series of observations are needed for this purpose it will take quite some time before any results can be reached in this way. The suggestion has been made that very distant objects like spirals might be used. They are so far away and their proper motions are so small that we shall be justified in postulating that the mean of their angular motions is zero. Thus, if we determine the position of stars in the catalogues relative to the spirals at a certain time and if, after a suitable number of years, we repeat the observations the eventual change in the star positions should give a far more reliable picture of stellar motions than we have hitherto been able to procure. This program is very large. The plates are of square plate glass and of size 17 × 17 inches and well over 1100 have to be used to cover the visible part of the sky. Each plate costs, as far as I remember, over four dollars, hence it is also an expensive undertaking. The measurement of these large plates will represent the greatest part of the work and a special measuring machine will have to be built.

While such extensive programs of observations are going on as was roughly sketched here, occasional discoveries are made. The Lick Observatory does not make a practice of "comet hunting"; nevertheless 33 new comets have been found in the course of time, among them the first which was ever discovered photographically. The Observatory also has the honor of the discovery of four of Jupiter's satellites, among them the fifth, very faint moon which is closer to Jupiter than any of the four old and well-known ones. It was discovered in 1892 by Barnard with the 36-inch refractor, while the three others, Nos. 6, 7, and 9, all were found on photographs taken with the Crossley reflector, Nos. 6 and 7 by Perrine and No. 9 by Nicholson.

Life on Mt. Hamilton starts very early: at 8 A.M. all those who did not observe the preceding night are expected to be in their offices and shortly before 8 the astronomers are seen leaving their houses and converging towards the main building. As those who live farthest away

[1] For instance the orbit of the asteroid 51 Nemausa is being carefully determined at the Copenhagen Observatory for this purpose.

from the offices have a walk of 10-15 minutes some arrive in their cars but those a little less lazy go in for the morning walk, and if the winter gales do not rage around the mountain ridge this walk is very beautiful with its wide views over the surrounding country where the fog often lies, bathed in sunshine, as white cotton blankets in the valleys and deep canyons. Those who have observed do not make an appearance before later in the morning and their first steps are then generally directed to the photographer to learn how the plates exposed during the night have come out. Shortly before noon a slight commotion starts in the main building and in the work shops and people scan the winding mountain road for the mail car which once every weekday brings mail and food to the various households. The married members of the staff all have their own houses, the unmarried astronomers live together in a three-storied dormitory and a cook is engaged to look after their needs. The women are given two nicely furnished rooms with a bath while the men's quarters are somewhat more Spartan. After lunch the work goes on in the first hours of the afternoon, and afterwards people sun themselves on the terraces while the more energetic ones take walks along the mountain trails, go horseback riding or play tennis. At 6 P.M. practically the whole observatory staff dines and then it is time for those who have to observe to get into their observing garb and start heating the spectrograph or cooling the photometer, and the road becomes lively with cars running between the houses, the main building with the 36-inch refractor, the Crossley dome, and the 20-inch astrograph. The work is generally done in two shifts, each of a half night's duration. The others who are not booked for observation that night arrange themselves cosily in front of their open fireplaces with books, radio, or an occasional game of bridge if they do not drive down to San José for a movie or a concert. On Saturday nights, in normal times, the main building is a place of great commotion, for then the Observatory for a couple of hours is open to visitors. On fine clear nights great numbers of cars make the trip to the mountain top. Both the astronomers and the members of the non-scientific staff have in turn to assist on these visitors' nights to handle the instruments and to keep order in the halls and domes. As the staff is so numerous these visitors' nights can take place without too much disturbance or annoyance to the staff.

In normal times about 50 persons live on Mt. Hamilton but during the war the number was reduced to some twenty, as many astronomers became engaged in war work whether it took place in laboratories in cities or deserts or as advisers to the Air Force (for instance the flying super-fortresses). Unfortunately the Observatory lost one of its very fine young astronomers, Dr. Arthur B. Wyse, in an accident during such scientific war work.

A difficulty for the married astronomers is the education of their children. The Observatory has its own school house to which the State

of California sends a teacher if a sufficient number of children is at hand in the Observatory and in the ranch houses in the vicinity. This arrangement is fairly satisfactory as long as the children are small but far from so when they grow older, also very often there are not enough children to justify a resident teacher. It has been proposed to change the system of work in the direction of that used at the Mt. Wilson Observatory, the more so because the main site of the University of California is located in Berkeley at a distance of about 60 miles. The astronomers would then have their domiciles in Berkeley and only spend those nights for which they are listed for observations at the Lick Observatory. Such a plan would of course totally change life on Mt. Hamilton and much of the charm of the present arrangement would disappear. On the other hand it has to be admitted that better possibilities would arise for co-operation with University colleagues working for instance in physics, mathematics, and chemistry, a co-operation that might prove very fruitful to all parties.

Just recently the Observatory has received, from the State of California, a grant of $1,200,000 for the construction of a new 120-inch reflector, and the engineers have started work on its design. This instrument should particularly be used for exploring the spiral nebulae, and the wish may be expressed for the new director of the observatory, Dr. C. D. Shane, that no postwar disturbance may impede his plans. Such an instrument in connection with the well-seasoned older telescopes and the double astrograph will preserve for the Lick Observatory its place among the leading observatories of the world.

OBSERVATORY, COPENHAGEN.

A Vanished Lunar Crater

By H. PERCY WILKINS*

Towards the end of the 18th century the celebrated observer, Schroëter, engaged in a careful study of the moon with a reflecting telescope of six inches aperture was desirous of finding some distinct object, near the limb, measurement of which would indicate the existing libration. Libration is an apparent swaying of the moon which alternately brings into and carries out of view regions which are close to the edge or limb in mean or average conditions and greatly affects the proportions of objects situated in those regions which, while not actually carried out of view, are in proximity to the zone thus affected.

One of the most prominent features of our satellite and not far from the limb is the small dark plain or "sea" known as the Mare Crisium. To the naked-eye it is the first distinct spot to appear in the crescent and

*F.R.A.S., Director of the Lunar Section of the British Astronomical Association.

Schroëter noted a large, distinct crater with bright walls and dusky floor in the middle of the western border. In his interesting "Selenotopographische Fragmente" Vol. I, appears a drawing of the Mare Crisium showing the principal objects on its surface fairly accurately placed but only two objects along the whole length of the border, this crater called Alhazen and a mountain to the south. Visible under all angles of illumination it was used as a convenient reference point and must therefore have been a conspicuous object.

Yet today a small telescope will show that this crater no longer exists. What will be seen are mountains on either side of where, according to Schroëter, it used to be, that on the east being especially prominent. This is the appearance shown in the lunar maps of Lohrmann, Madler, and Schmidt as well as in photographs and the modern maps of Goodacre and the writer. Madler, who could not find it, transfered the name to a crater farther south.

If Schroëter's drawing is accepted as a reasonably accurate representation of this portion of the moon 150 years ago, and it is difficult to understand how he could have repeatedly measured its distance from the limb if it did not exist, we cannot escape the conclusion that a change of some sort must have taken place. There is, indeed, evidence that the early telescopists saw a crater there as it appears in the rough chart of De Rheita while there is also an object in the correct position in the beautiful old map of Tobias Mayer.

Although Schroëter omitted many sufficiently prominent details he never drew anything he did not see. Neison, indeed, declared the four large pits shown in his drawing of Ptolemaêus to have no existence but these pits, although depicted too strongly, correspond to real objects. They are, in fact, identical with the shallow saucer-like depressions peculiar to this formation and appear on the modern charts of Saunders, Goodacre, and the writer. There can be little doubt that the crater existed in Schroëter's time; it is certain it does not exist today and the question arises as to how a 23-mile diameter crater could have vanished without leaving a trace.

Ruling out the possibility of mistake there appear to be three possible explanations: (a) change due to sub-lunarian forces, *i.e.,* eruptive or erosive volcanic activity, (b) change due to extraneous influences, *i.e.,* meteoric bombardment, (c) obscuration or surface tint alteration of the still existing crater.

It is difficult to reconcile the present practically static condition of the lunar surface with volcanic activity of such intensity as to obliterate a 23-mile crater; it is equally difficult to realize such an effect from meteoric impact; rather it would seem that the fall of a larger meteor would increase the depth and not level an already existing hollow.

Alhazen was described by Schroëter as well defined, visible under all angles of illumination and remarkable for the grey colour of its

interior. It was the latter feature rather than the height of the walls or the depth of the cavity that rendered the crater a prominent feature even under high illumination when, owing to absence of shadow, it is difficult and often impossible to distinguish elevations from depressions. Alhazen 150 years ago was a large crater with bright walls considerably elevated above the outer surface and a grey slightly depressed interior. If the variety of tint was followed by variation of tint so that the grey interior faded or bleached until it became the same as the walls, all contrast would be lost and with it the appearance of a crater. Instead of a slight colored depression it would appear as a level surface between two mountains which it is today.

Many formations, indeed a large part of the brighter portion of the surface, undergo variations of tint of a more or less periodic nature and no surprise should be felt at a permanent alteration of tint within one of the numerous lunar rings. Eratosthenes, the surface near Hyginus, Aristarchus, Schickard, and Plato are but a few of many regions which clearly exhibit tint variations. Schroëter's Alhazen is but an example, and possibly not the only one, of a permanent change of tint.

This tint alteration may have been due to some such cause as that outlined in "The Glassy Crust of the Moon" (*Popular Astronomy*, May, 1946). It may have resulted from the formation of some crystalline substance, an oozing out of salts or even the covering of the grey interior by a light colored dust. Whatever the cause it can hardly be doubted that to account for the disappearance of this celebrated object we need not visualize violent volcanic eruptions or the impact of huge meteoric masses, a mere color alteration is sufficient. We see no crater, nothing except a level surface flanked by mountains. Schroëter saw both level surface and mountains but to him the surface was dark which contrasting strongly with the surroundings immediately marked it as a distinct formation.

What has happened once can happen again hence the importance of observations to note the tint and brightness of lunar formations. Although commonly neglected it is amongst the shades and surface tints that evidence of changes on the moon will be found and in their study we reconcile our views with those of the old Hanoverian observer just as from our records the selenographers of the 21st century will deduce evidence of further changes on the surface of the only celestial body we can study in minute detail.

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The Square Degree as a Unit of Celestial Area

By DAVID VANCE GUTHRIE

One of the first things the beginner in astronomy has to learn is that the apparent distance apart of two stars in the sky or the apparent diameter of the moon is to be expressed in angular, not linear units. Thus the distance between the two pointer stars in Ursa Major is 5° of arc, the diameter of the full moon is half a degree. It follows that a certain area of the heavens should be expressible in terms of square degrees.* Although this unit is not to be found in mathematical treatises and seems to be unfamiliar to most mathematicians, it is very commonly used by astronomers and proves quite useful in this field. It becomes of interest, then, to determine the number of square degrees in the visible hemisphere and incidentally to note some useful relations in connection with determination of areas on spherical surfaces.

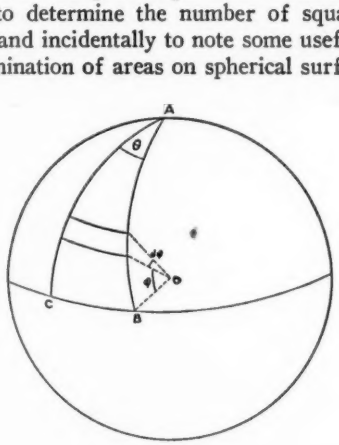

FIGURE 1

Let us consider the semi-lune ABC on the surface of a sphere, this being the area comprised between the equator and the meridians AB and AC, forming an angle θ with each other. Let us consider the elementary area bounded by the parallels whose latitudes are ϕ and $\phi + d\phi$. The radius of the arc whose latitude is ϕ is evidently $r \cos \phi$, r being the radius of the sphere, and the length of the arc is $r \cos \phi \cdot \theta$. The width is $rd\phi$. The area comprised between the two meridians and the two parallels is then

$$r \cos \phi \times \theta \times rd\phi = r^2 \theta \cos \phi d\phi.$$

*A square degree may be defined as the part of a sphere intercepted by the faces of a square pyramid having the vertex at the center of the sphere, the face angles being each one degree. Any area on the surface of the sphere equal to this, regardless of its shape, may be considered an area of one square degree.

Integrating this from the equator to the pole, we obtain

$$\text{Area ABC} = \int_0^{\pi/2} r^2 \theta \cos\phi d\phi = r^2 \theta \sin\phi \Big]_0^{\pi/2} = r^2\theta,$$

θ of course being expressed in radians.

Let BC = s.

Then, since $s = r\theta$, area ABC = rs.

Thus the area on the earth's surface comprised between two meridians and an arc of the equator may be obtained by multiplying the radius of the earth by the linear distance along the equator, or by multiplying the square of the earth's radius by the angle between the two meridians expressed in radians.

The area comprised between any two parallels, at latitudes ϕ_1 and ϕ_2, and any two meridians at longitudes θ_1 and θ_2 (expressed in degrees) may readily be found by this method. Dividing degrees by 57.29, the number of degrees in a radian, in order to change to radians, and neglecting the slight departure of the earth's surface from a perfect sphere, we have the area equal to

$$r^2 \frac{(\theta_1 - \theta_2)}{57.29} (\sin\phi_1 - \sin\phi_2).$$

Thus the State of Colorado, which is bounded by the parallels 37° and 41° and by the 102nd and 109th meridians, has an area

$$\frac{(3963.4)^2 \times 7}{57.29} (.65606 - .60182) = 104{,}100 \text{ square miles.}$$

The area of the hemisphere is seen from the formula $r^2\theta$ (making $\theta = 2\pi$), or the formula rs (making $s = 2\pi r$), to be $2\pi r^2$.

Another formula may be obtained as follows:

$$\text{Area of ABC} = rs = OB \times BC$$
$$AB = \tfrac{1}{4} \times 2\pi \times OB = \pi/2 \times OB.$$

Therefore

$$OB = 2/\pi \times AB$$

and

$$OB \times BC = 2/\pi \times AB \times BC = 2/\pi \text{ sh (representing BC by s and AB by h).}$$

Thus, while the area of a plane triangle is one-half the product of the base by the altitude, the area of a triangle such as this is $2/\pi \times$ base $\times$ altitude.

We now have three alternative formulas for the area of the spherical triangle ABC:

$$\text{Area ABC} = r^2\theta = rs = 2/\pi \text{ sh.}$$

Let us express all linear lengths of arc on the sphere in angular units. We may do this if we regard the radius of the sphere as unity. Then lengths of arcs will be numerically the same as the angles which they subtend at the center. Thus the area of the state of Colorado could just as well have been expressed in square degrees if a degree of latitude were as convenient a unit of length as a statute mile. In fact mariners always use the minute of latitude (called the nautical mile) as their measure of distance.

Using the third of the formulas developed above, for the hemisphere s becomes the length of the equator, $2\pi r$ or 360° of arc, and h, the distance from the equator to the pole, is $\pi r/2$ or 90°. Then the area of the hemisphere $= 2/\pi \times 360 \times 90 = 64800/\pi = 20{,}626.48$ square degrees.

The same result may be obtained by making use of the unit of solid angle, the steradian. A square radian may be defined as that area on the surface of a sphere which is subtended by the unit of solid angle, the steradian. (An angle in steradians is equal to the area it subtends on the surface of a sphere divided by the square of the radius of the sphere). Then the area of the hemisphere, which subtends a solid angle of 2π steradians, must be 2π square radians. Since one radian $= 180/\pi$ degrees of arc, the area of the hemisphere must be $2\pi\ (180/\pi)^2 = 20{,}626.48$ square degrees, agreeing with the result obtained above.

A knowledge of this number is useful in many different fields of astronomy. One of the most important of these is the calculation of the number of full moons which would fill the sky. The statement is frequently made that if the whole sky were packed with full moons, the total light received would be only one-fifth of the light we receive from the sun. In order to verify this statement, we note that the best determinations of the intensity of the light of the full moon give it as 1/465,000 of that of sunlight. It may be of interest to note that the earth receives as much heat and light from the sun in 13 seconds as it receives from the moon, going through all its phases, in a whole year. The intensity of the light of the full moon is about one-fiftieth of a foot candle, or about equal to the light received from a standard candle 7 feet away.

There may be ambiguity, when we speak of the sky as being filled with full moons, as to whether we mean the whole sky to be glowing uniformly with the brightness of the full moon or whether we think of the sky as packed with full moons tangent to each other. In the former case, we divide the total area of the sky in square degrees by the area of the moon's disk in angular measure.

In order to calculate the number of square degrees in a circular area such as that of the sun or moon on the celestial sphere, the formula for such an area is $4\pi \sin^2 \theta/2$ square radians or $129{,}600/\pi \sin^2 \theta/2$ square degrees, where θ is the angle subtended at the center of the sphere by the radius of the circle. Since for circles up to 5° in diameter

on the surface of a sphere, the formula for the area of a plane circle, πr^2, is approximately accurate to five significant figures, we may use it for computing the apparent area of the moon. We may take the average value of the moon's apparent diameter, which actually ranges from 29′ 27″ at apogee to 33′ 30″ at perigee, as 31′ 5″. (This is the average per unit time interval, since the moon moves rapidly through perigee.) The average area is then 0.21078 square degree. Dividing this into the number of square degrees in the visible hemisphere, we find that the brightness of the sky if illuminated uniformly with a brightness equal to that of the full moon would give us as much light as 97,855 moons. But assuming that the full moon gives only 1/465,000 as much light as the sun, we find that the total light received would be only 97,855/465,000 = 1/4.752 (or just a little more than one-fifth) as much light as the sun gives.

If we make the other assumption, that the sky is filled with full moons tangent to each other, we may note that the ratio of the area of a plane circle (area πr^2) to the area of the circumscribed square (area $4r^2$) is $\pi/4$. For a spherical surface the same ratio holds approximately for circles as small as the moon's disk. From this we may conclude that the number of moons required to fill the visible hemisphere would in this case be only $\pi/4$ as many as the former case, where the whole area was occupied. This gives us 76,855 as the number of moons tangent to each other which would fill the sky. The ratio of light received would then be in the present instance 76,855/465,000 = 1/6.05 or very nearly one-sixth.

In Herschel's famous study of the distribution of the stars in different parts of the heavens, which led to the first picture of the galactic system, he made thousands of "star gauges," counting the number of stars which could be seen in the 15′ field of view of his 18-inch reflector. Realizing that it would be practically impossible to cover the whole heavens in this manner, he studied 3400 regions which he assumed to be typical. The same scheme has been followed by many observers since that time. We may utilize our knowledge of the number of square degrees in the visible hemisphere to calculate how many settings of his telescope would be required to cover the whole sky. The arc of a 15′ circle is $\pi/64$ or 0.049 square degree. From this it is seen that 20,626/.049 or approximately 421,000 times the field of Herschel's telescope would be needed to cover the whole of the heavens, and, due to necessary overlapping of circular fields, nearly twice that number of actual settings would have to be made.

There are many problems of astronomy for which a knowledge of the area of the visible hemisphere in square degrees may be useful, but the ones cited above are possible the most important. The writer wishes to acknowledge his indebtedness to Professor Raymond H. Wilson, Jr., of Temple University for valuable comments and suggestions.

Louisiana State University Observatory, Baton Rouge, Louisiana.

Sunspots and Levels of Lakes in Minnesota

By FRANKLIN J. RYDER*

We in Minnesota boast of 10,000 lakes within our state. Among the larger of these lakes are Lake Traverse on the Minnesota-South Dakota boundary, and Lake Superior bordering the state on the northeast, (see Figure 1). From the early 18th century, English and French explorers and later settlers and government agents venturing into the northwest territory chronicled incidents indicative of relative levels of these lakes. In more recent times government agencies have published lake stage data.

Incidentally, records of temperature and precipitation in the vicinity of Minneapolis cover a period of approximately a century and a quarter. Medical officers of the U. S. Army began to record daily temperatures in 1819 when troops first arrived at Fort Snelling, a military reservation to the southeast of Minneapolis. Precipitation records were started in 1837. By combining the observations of the army medical officers, and the later records of the Army Signal Corps and the Weather Bureau, the climatological records for Minneapolis are continuous for 126 years, longest for any station in midwestern United States. With this wealth of data, let us begin our study of the relation of lake levels and sunspots.

Temperatures and Precipitation at Minneapolis

Relative lake levels are directly proportional to rainfall and inversely proportional to evaporation. Evaporation rates in turn are dependent on temperature, wind, and humidity. As rainfall decreases and as temperature and evaporation rates remain static or increase, lake levels will be lowered. However, fluctuation in lake levels fall behind by several months any fluctuation in precipitation because of the time necessary for runoff from a lake's drainage area to find its way into the lake.

Temperatures have been recorded daily in the Minneapolis area since 1819, and precipitation has been recorded since 1837. Mean annual values of rainfall and temperature at Minneapolis were subjected to a five-year moving average, to which a second five-year moving average was applied. I am convinced that this second five-year moving average is indicative of trend. (A graph of these second five-year moving averages accompanies this paper, see Figure 2.)

Trend of temperature rose from 1819 to a peak in 1835, falling to a low in 1871, and ascending to the present time. Minor peaks in temperature were reached in 1878, 1922, and 1930. Noticeable low points

*Junior, American Society of Civil Engineers.

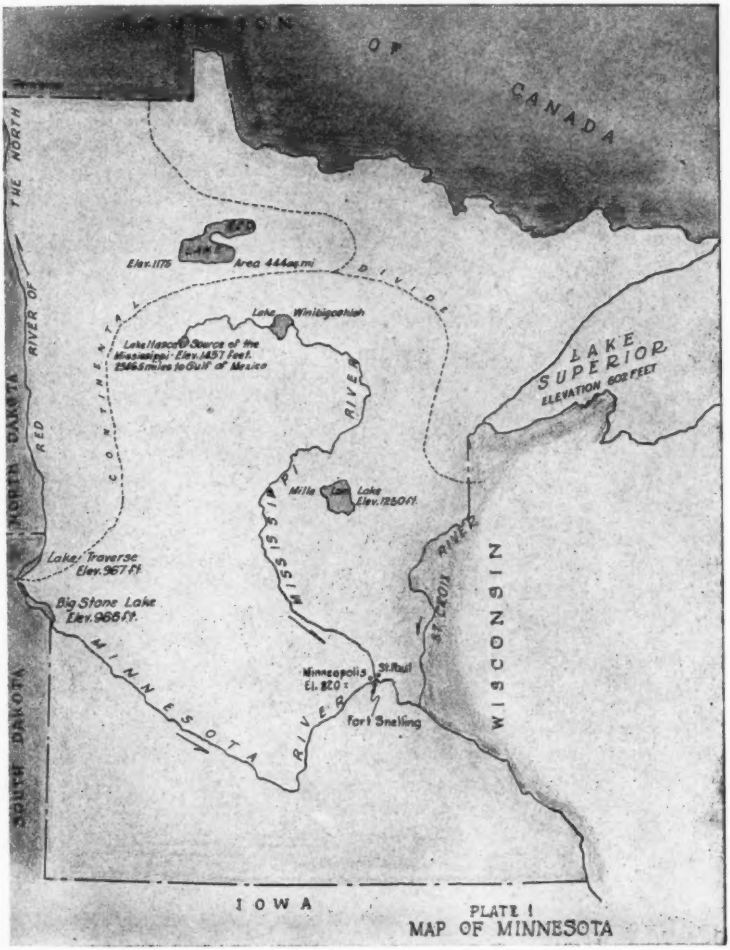

FIGURE 1
MAP OF MINNESOTA

in trend occurred in 1857, 1867, 1883, and 1935. Since 1930, the temperature trend has been on the down grade.

The trend of precipitation at Minneapolis is almost the inverse of the trend of temperature, although lagging by about two years.

LAKE TRAVERSE

Lake Traverse, and Big Stone Lake immediately to its south, are

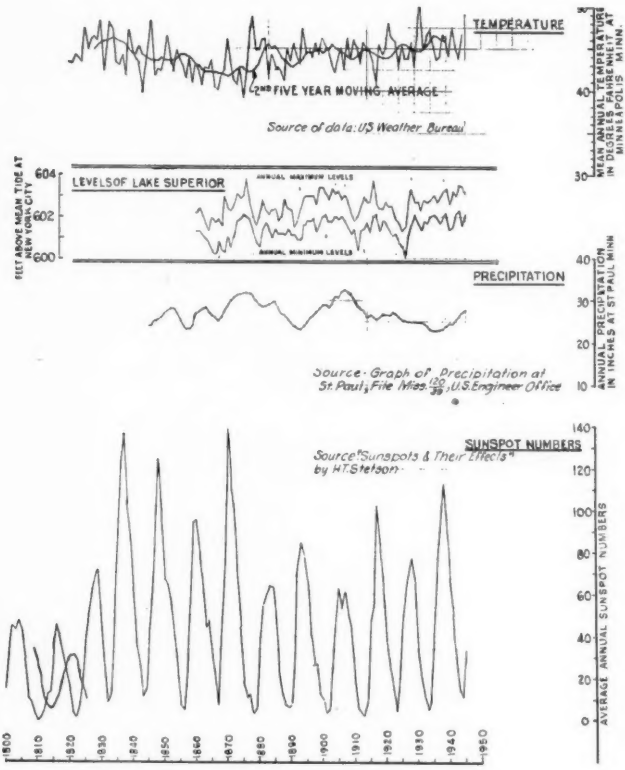

FIGURE 2

ANNUAL PRECIPITATION AND ANNUAL TEMPERATURES AT MINNEAPOLIS AND ST. PAUL, MINNESOTA. SUNSPOT NUMBERS AND LEVELS OF LAKE SUPERIOR.

located on the boundary of Minnesota and South Dakota. These lakes are separated by a very low, natural dike. Big Stone Lake is drained by the Minnesota River which joins the Mississippi River at Fort Snelling. Lake Traverse flows into the Red River of the North which eventually empties into Hudson Bay.

Lord Selkirk—that enterprising Scotch philanthropist—acquired in 1811 a vast tract of land to the west and south of Lake Winnipeg. Selkirk's superintendent, Laidlow,[1] set out from Pembina, Manitoba, in April of 1820, passed up the Red River of the North, through Traverse and Big Stone Lakes, down the Minnesota and Mississippi Rivers to Fort Crawford (later Prairie du Chien) Wisconsin, to buy

grain. On his return trip, Laidlow in passing from Big Stone Lake to Lake Traverse was forced to place his boats on rollers, and drag them over the divide between the two lakes. Here is evidence that Traverse and Big Stone Lakes were low. Wolf sunspot numbers reached a low in 1821.

In 1823, Major Stephen H. Long, directed by the War Department to make a survey of the International Boundary between Canada and the United States, left Fort Snelling, travelled up the Minnesota River and down the Red River to the Canadian border. William Keating who wrote an account of the Long expedition[2] said that ". . . the space between Lake Traverse and Big Stone Lake is but very little elevated above the level of both lakes; and the water has been known in times of floods to rise, and cover the intermediate ground, so as to unite the two lakes." From Keating's remarks, one would gather that Traverse and Big Stone Lakes were near flood stage in 1823—and much higher than in 1820. Dr. William Watts Folwell, first president of the University of Minnesota, recounts that a flood occurred in 1826 on the Red River of the North. Lake Traverse must have been very high at that time. Sunspot numbers were also rising from a low in 1821 to a peak in 1828.

Featherstonehaugh, a government geologist, reported that in 1835 the "channel which it (Lake Traverse) communicates with the Red River . . . was dried up . . . and Lake Traverse had consequently become stagnant." Sunspot numbers reached a low point in 1832.

Havinghurst in his "Upper Mississippi River, a Wilderness Saga"[3] tells of a river Captain, John B. Davis by name, who won a certain amount of fame in taking river boats over sunken bars and ridges. Davis in 1859, took his boat on a short cut across a stretch of inundated land between Big Stone Lake and the Red River of the North. He succeeded well for a short time but his ship was later grounded on the prairie and wrecked ten miles from the proper channel.

A recent biography of the famous surgeons, the Mayo brothers of Rochester, Minnesota, also refers to the 1859 flood on the Minnesota River, which isolated communities along the river, marooned residents in their homes, inundated roads, and halted operation of ferries.[4] These floods of 1859 occurred in a year of maximum sunspot numbers.

Lake Superior

Records of levels of Lake Superior compiled by the Corps of Engineers, U. S. Army, cover the period from 1860 to date. These records indicate both an annual and a secular cycle in Lake Superior's stage.

Within each year, Lake Superior reaches a low point sometimes as early as December, occasionally as late as April, and on an average in March; rises to a high stage in late summer, usually in July or August, and falls again to a low in the late winter or early spring of the following year. The annual fluctuation of Lake Superior amounting to ap-

proximately one foot, is due to the action of spring ice-melt, and early summer rains.

Now, let us examine the secular fluctuations of Lake Superior. The long-time trend of levels of the lake varies directly as the trend of precipitation at Minneapolis, and fluctuates inversely as temperature trend. As trend of precipitation (previously referred to second five-year moving average) rises or falls, so too, Lake Superior rises or falls almost in unison. As the trend of temperature changes, the trend of precipitation and Lake Superior levels change in the opposite direction. This relation between temperature and precipitation trends and the stages of Lake Superior is particularly evident in the period 1872-1878. The trend of precipitation was at maximum from 1874 to 1878. Lake Superior reached the highest point of record in 1876, and the mean annual temperature at Minneapolis for the year 1875 was 38° F., the lowest ever reached. A similar situation existed in 1883.

A minute comparison of levels of Lake Superior with sunspots indicates only an indirect relationship between the two. Mr. B. H. Wilson in *Popular Astronomy*,[5] says of Lake Michigan that "for every complete cycle, each sunspot maximum year coincides with or is followed by the periodical year of highest lake elevation; and likewise each sunspot minimum year also coincides approximately with years of minimum lake elevations." Fluctuations of Lake Superior do not seem to coincide so precisely with sunspot variations. However, years of large sunspot numbers coincide almost exactly with years of low temperatures at Minneapolis; and years of low sunspot activity match years of rising temperatures. Years of maximum sunspots occur during, or are closely followed by, a rising trend in precipitation, and periods of low sunspots coincide with a decrease in precipitation. Lake Superior rises and falls in unison with the trend in precipitation, and fluctuates inversely to temperature. Therefore, it appears that any change in the level of Lake Superior is only indirectly associated with any sunspot activity.

Those familiar with sunspots know that sunspot maxima occur on an average at 11-year intervals. Beginning with the mean annual sunspot number for 1837, and taking such sunspot numbers for alternate years of maximum sunspot activity (1837, 1860, 1883, 1905, 1928), such numbers roughly describe a trigonometric sine curve with a high spot in 1837, a trough at about 1900, and which may peak again in about 1965. The trend of temperatures at Minneapolis seems to be of the same shape as this sunspot sine curve, although slightly out of phase. Definite peaks in both Lake Superior's levels and the trend of precipitation at Minneapolis occur both before and after the low in sunspot sine curve. Perhaps someone with a mathematical turn of mind may develop this apparent relationship.

Summarizing, both Lake Traverse and Lake Superior are high when sunspots are at maximum, and the weather is cool and wet. In years of

low sunspot numbers, the reverse is true. The Great Salt Lake in Utah seems to possess these same characteristics as Lake Superior.[6]

A cursory study such as this seems to indicate that there is a complex kinship between sunspot activity, temperatures, precipitation, and fluctuation in lake levels. Lake levels are directly dependent upon temperatures and rates of precipitation; undoubtedly a more remote cause of variations in temperature and precipitation is intimately related to the factors producing sunspots. Sunspots in themselves are at best, mere indications of solar forces at work. The evaluation of the effects of these solar forces, as evidenced by sunspots on lake levels and weather, is of prime importance.

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The Planets in May, 1947

By LELAND E. CUNNINGHAM

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will move slowly northward throughout May, and will be within two degrees of its northernmost declination by the end of the month. There will be a total eclipse of the sun on May 20; it will be visible as a partial eclipse throughout most of South America and Africa. The path of totality begins at local sunrise just off the west coast of South America, runs northeastward across the continent, enters the Atlantic Ocean near the tip of Brazil, crosses the ocean at its narrowest part, runs along the northern shore of the Gulf of Guinea, crosses Africa near the equator, and ends at local sunset just short of the Indian Ocean. The maximum duration of 5 minutes 14 seconds will occur in the Atlantic Ocean; however, on the coasts of Brazil and Africa the duration will be four minutes, and several parties are preparing to travel to these locations to observe it.

Moon. The phases of the moon will occur as follows:

		C.S.T.
Full Moon	May 4	11 P.M.
Last Quarter	13	2 A.M.
New Moon	20	8 A.M.
First Quarter	26	11 P.M.

Evening and Morning Stars. Saturn will be the only conspicuous evening star. Jupiter will be an all-night star near opposition. Venus will continue to be a brilliant morning star, and Mars an inconspicuous one nearby.

Mercury. At the beginning of the month Mercury will be west of, and approaching, the sun. It will be in superior conjunction on May 15, after which date it will move out into the evening sky, but not far enough to be seen by the end of the month.

Venus. Venus will continue its eastward motion in the morning sky a little more rapidly than the sun; by the end of the month it will be only 25 degrees from the sun.

Mars. Mars will continue its very slow motion out into the morning sky, but will remain inconspicuous. It can be easily located on May 17, when it will be about one degree north of Venus.

Jupiter. Jupiter will be in opposition to the sun on May 14; it will be retrograding in Libra. The fifth of the series of monthly occultations by the moon will occur on May 5, but will be visible only in southern latitudes.

Saturn. Saturn will be well past the meridian at dusk, and so will not be in such a fine position for telescopic observation as in April. It will be moving slowly eastward in Cancer.

Uranus. Uranus will be too close to the sun for observation.

Neptune. Neptune will continue its retrograde motion in Virgo.

Students' Observatory, University of California, Berkeley, March 18, 1947.

Occultation Predictions for May, 1947

(Taken from the *American Ephemeris*)

Date 1947	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
May 8	136 G.Ophi	6.3	6 50.2	—1.7	—0.7	133	8 8.0	—2.1	—0.1	251
9	66 B.Sgtr	4.7	5 30.6	—0.6	—0.4	145	6 31.0	—2.5	+1.6	237
27	46 Leon	5.7	2 21.3	—0.8	—1.8	117	3 24.9	—0.3	—1.8	303
30	48 Virg *m*	6.5	5 21.7	—0.6	—2.2	146	6 20.5	—0.4	—1.5	273
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
May 6	*κ* Libr	5.0	4 51.7	—2.0	+1.1	86	5 59.8	—0.9	—1.3	335
8	136 G.Ophi	6.3	6 32.7	0.0	—1.8	167	7 17.9	—3.3	+2.2	229
27	46 Leon	5.7	2 11.9	—0.7	—2.4	150	3 15.1	—1.3	—1.3	275
30	48 Virg *m*	6.5	5 16.4	—0.5	—2.7	169	6 8.0	—1.4	—1.1	258

Date 1947	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
May 9	69 G.Sgtr	6.3	10 37.6	−3.3	+2.9	34	11 26.0	−2.4	−2.8	335
Occultations Visible in Longitude +98° 0′, Latitude +30° 0′*										
May 6	41 Libr	5.5	2 45.4	−0.1	−0.5	137	3 50.6	−1.1	+0.5	284
6	κ Libr	5.0	4 37.4	−1.0	−0.4	126	5 59.2	−1.9	−0.5	299
9	69 G.Sgtr	6.3	11 23.9	−2.0	+0.6	54	12 42.4	−2.2	−1.8	294

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U. S. Naval Observatory.

The quantities in the columns a and b are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under a for the star to be observed; similarly, with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Asteroid Notes

By HUGH S. RICE

In this issue we are continuing the ephemerides of the three minor planets given in the last issue.

Aspasia arrives at opposition May 10. At the end of April its predicted photo-magnitude is 11.2. Eunike arrives at opposition May 26. At the end of April its predicted photo-magnitude is 11.9. Mnemosyne arrives at opposition May 28. At the end of April its predicted photo-magnitude is 12.4. The visual magnitudes of these planets may be roughly a magnitude brighter than the above.

511 Davida was discovered by Dugan at Königstuhl on May 30, 1903. It was then of magnitude 10.5, and was observed a little over two months. For the present observing period Davida is in southern Boötes, and the magnitude is about 10, placing it within reach of small telescopes. The date of opposition at this apparition is April 20.

454 Mathesis was discovered by Schwassmann at Königstuhl on March 28, 1900. It was then of magnitude 11.2, and was observed for three months. For the present observing period Mathesis is in eastern Virgo, and the magnitude is a little less than 11. The date of opposition at this apparition is April 25.

3 Juno will be well placed for observation during spring and summer. For the present observing period Juno is in central Serpens Cauda, and the photo-magnitude is 11.5 to 11.2. However, it will brighten up considerably, reaching maximum at opposition time in June. We have, in the past, often observed it with 50-mm Zeiss, at magnitude around 9.

For the planets continued from March, we are indebted to Dr. Dirk Brouwer, of Yale U. Observatory; and for the new ones we are indebted to Dr. L. E. Cunningham, of the Students' Observatory, of the U. of California.

ASTEROID EPHEMERIDES

For 0^h U.T. Equinox of 1947.0

511 DAVIDA

1947	α h m	δ ° ′
April 5	14 1.5	+11 2
13	13 56.6	+11 34
21	13 51.4	+11 58
29	13 46.3	+12 10
May 7	13 41.6	+12 11
15	13 37.6	+12 3

454 MATHESIS

1947	α h m	δ ° ′
April 5	14 22.1	−13 7
13	14 15.6	−13 1
21	14 8.2	−12 51
29	14 0.5	−12 38
May 7	13 53.2	−12 26
15	13 46.9	−12 17

409 ASPASIA

1947	α h m	δ ° ′
April 15	15 24.0	−25 7
20	15 21.0	−24 38
25	15 17.6	−24 5
30	15 13.6	−23 28
May 5	15 9.4	−22 47
10	15 5.0	−22 3
15	15 0.7	−21 16

185 EUNIKE

1947	α h m	δ ° ′
April 15	16 31.6	+ 9 29
20	16 30.0	+10 16
25	16 27.8	+11 0
30	16 25.2	+11 41
May 5	16 22.1	+12 18
10	16 18.6	+12 51
15	16 14.8	+13 18

57 MNEMOSYNE

1947	α h m	δ ° ′
April 15	16 40.9	− 9 49
20	16 39.5	− 9 21
25	16 37.6	− 8 52
30	16 35.3	− 8 23
May 5	16 32.6	− 7 54
10	16 29.6	− 7 26
15	16 26.3	− 6 59

3 JUNO

1947	α h m	δ ° ′
April 15	18 7.6	− 8 8
20	18 8.2	− 7 44
25	18 8.1	− 7 21
30	18 7.6	− 6 58
May 5	18 6.5	− 6 35
10	18 4.9	− 6 13
15	18 2.8	− 5 53

Hayden Planetarium, American Museum of Natural History, New York, N. Y., March 22, 1947.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Our annual report for 1946 will have to differ from former ones in an important respect. As is well known, and as previous Meteor Notes and others yet to come set forth in detail, many tens of thousands of meteors were counted and some few were plotted on the night of October 9 during the great shower of Draconids. In these notes, I have attempted to give in detail what was reported, each person being given credit by name, where practicable. It does not seem reasonable to repeat these long tables of data in the annual report, and so nothing seen from October 8 to 10 inclusive, when observers were intent on the Draconids, is included here. The routine work of the year will be covered as usual.

We were unfortunate in 1946 due to moonlight spoiling the Perseid maximum

and also seriously interfering with work on several of the richer annual showers. Further cloudy weather in many areas of the United States on the critical dates made work impossible. Also the year was an unsettled one: some of our younger members being drafted, and others just being released from service were unable to take up at once where they left off. Also a few have been slow about reporting and their results are not yet in my hands, and hence will have to be mentioned at a later date. Nevertheless, a respectable amount of work was done, and we find several names in the table with considerable totals indicating that we are gaining new and active members. However, as has been the case for several years past, we find our able member from India, Professor Mohd. A. R. Khan, has done by far the most observing. He is further to be congratulated on arousing interest in astronomy in general and meteors in particular among his countrymen. In this country, Professor J. Hugh Pruett of the University of Oregon has accomplished most in his territory, which comprises the north-western states, to advance the cause of meteoric astronomy. There are now two active groups of young observers in New York City, one known as the Crotona Observers, the other as Association of Amateur Observers. They are, however, much handicapped by the locality. One of the latter group, Edward Oravec, now in the U. S. Navy and in the Pacific, has sent in interesting reports from there. We also have belated ones for 1941 and 1945 from Koziro Komaki, one of our Japanese members, which could not reach me earlier due to the war. We are also beginning to receive reports from several amateur societies whose interest in meteors was aroused by the great Draconid shower.

As to telescopic meteors, C. F. Fernald again has outstripped everyone by a splendid report of 71 for the year. We still vainly attempt to secure the cooperation of most variable star observers in this program. Why they refuse it, I do not know. Now that the war is over the *Hydrographic Bulletin* of the U. S. Navy has resumed its valuable cooperation by publishing reports on fireballs seen from ships at sea. We have also received the usual cordial help of the daily press during the past year, particularly in giving out instructions for observing and advance information on the great October shower. *Flower Observatory Reprint* No. 67, containing the Meteor Notes for 1946, will soon be distributed. It will go at once to members who have paid their 1947 dues. Incidentally, very many have neglected to do this and their attention is hereby called to the necessity of sending them.

In 1947 the Moon will affect the main annual showers as follows: Lyrids, no moonlight; Eta Aquarids, spoiled by full Moon; Delta Aquarids, should be free of moonlight for the last couple of hours before dawn on July 28; the Perseids will have Moon at last quarter on August 9, hence with less moonlight on August 11/12 at their maximum, but the Moon will be in wrong part of the sky. However, it should not interfere too much; the Orionids will come just before first quarter which is very favorable; the Leonids will have no moonlight and the same is true for the Geminids. In other words, 1946 is a very favorable year so far as moonlight at the maxima of the chief annual showers is concerned. There should be therefore an excellent record set by our members. There is no reason why at least a few, who are not over burdened by their professional or other duties, should not try to match the record of such an observer as Professor Khan. When we find more such able observers the Society will prosper as never before.

The writer has nearly completed his supplementary paper on long-enduring

meteor trains. It is hoped that it will appear during the present year when interest is so great concerning the upper atmosphere. The new paper has additions and corrections to what appeared in 1942 as *Reprint* No. 60 of the Flower Observatory, and also a much fuller discussion of the various problems involved.

Observer and Station	Nights	Meteors	Remarks	
Anderson, J., Fort Sheridan, Ill.	2	84	C	
Anyzeski, V., New Haven, Conn.	3	86	PC	*
Bidlake, Miss Margy, Pullman, Wash.	4	532	C	
Burlinson, M. A., Tucson, Ariz.	1	17	C	*
Burn, E. H., Wallingford, Pa.	1	24	C	
Burns, H. A., Spring Valley, N. Y.	3	62	P	
Dole, R. M., Cape Elizabeth, Maine	16	199	P	
Dupee, Mrs. Dorothy S., Barnstead, N. H.	10	297	D	
Fernald, C. F., Wilton, Maine	1	18	C	
Field, R., Greenville, S. C.	5	32	P	
Fisher, Mrs. D., Baltimore, Md.	1	60	C	
Fitzsimmons, S. C., Sibley, Iowa	2	57	P	
Fleischer, R., Troy, N. Y.	1	54	C	*
Graham, J. L., Salem, Ore.	2	83	C	
Hay, A. A., Chicago, Ill.	20	77	P	
Hukill, R. M., Wilmington, Del.	5	86	P	
James, J. P., Salem, Ore.	1	26	C	
Jensen, Miss A. K., Silverton, Ore.	4	80	C	
Johnson, L. T., La Plata, Md.	1	28	P	
Khan, Prof. Mohd. A. R., Begumpet, India	64	800	P	
Komaki, K., Kanaya, Japan	9	196	PC	
Larmoy, F., Flint, Mich.	3	64	C	
Long, Mrs. Berta, Dell Rapids, S. D.	7	84	C	
McKeon, Mrs. J. J., Titusville, N. J.	6	411	PD	
McNeill, W. S., St. Petersburg, Fla.	2	584	C	
Marshall, R. K., Cook Observatory, Pa.	2	53	C	
Olivier, C. P., Flower Observatory, Pa.	1	20	P	
Preucil, F., Joliet, Ill.	4	100	C	*
Pruett, Mrs. J. H., Eugene, Ore.	1	19	C	
Rosengarten, G., Brookline, Pa.	1	19	P	
Schmidt, L., Elgin, Ill.	1	64	D	
Scott, T., Nauvoo, Ala.	9	125	P	
Siekman, W. J., Jr., Batavia, Ill.	4	256	D	
Swihart, T., Elkhart, Ind.	12	90	P	
Thompson, Mrs. F., Eugene, Ore.	1	57	C	
Whitney, C. A., Milwaukee, Wis.	1	26	C	
New York City Groups:				
Borowitz, S.	4	98	P	
Epstein, E. S.	2	32	P	
Helfer, H. L.	1	23	P	
Hirsch, D.	2	23	D	
Kohn, K. N.	4	96	PD	
Rayna, G.	3	38	PD	
Chabot, H. L.	4	52	P	
Sochard, I.	1	51	D	
Oravec, E. G.	10	205	DP	
Talaperos, A.	1	73	D	
Waldmann, E.	25	117	P	
4 observers		46		
		5724		

Observer and Station	Nights	Meteors	Remarks
Telescopic Meteors:			
Fernald, C. F., Wilton, Maine		71	
Halbach, E. A., Milwaukee Astronomical Society, 1941, 8; 1942, 8; 1943, 17; 1944, 13; 1945, 2†		48	
Rosebrugh, D. W., Waterbury, Conn.		5	
Thomas, H. D., Portland, Ore.		2	
		126	
Fireballs		64	
Casuals		16	
9 observers reporting less than 18 each		76	
		156	
Total		6006	

NOTE: P plotted, D described, C counted, * that more than one observer's count is included.

†Complete data are given for each meteor and the observations were made with a 13-inch reflector.

Flower Observatory, Upper Darby, Pa., 1947 March 12.

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD

Department of Astronomy, University of California, Los Angeles 24

Observations on the Carolina "Craters" or "Bays"*

BRANDON BARRINGER
The Pennsylvania Company, Philadelphia 1

ABSTRACT

The Carolina "craters" or "Bays" seem unlikely to have had a meteoritic origin, because: *(a)* not one meteorite is known to have been indisputably associated with any of the hundreds of craters, tho many are very small; *(b)* the subsurface strata are undisturbed; *(c)* the smaller craters are not more "filled-in" than the larger; and *(d)* the symmetry of the Rains, South Carolina, group can hardly be explained by a chance distribution of 6 bodies traveling thru space.

The literature on the Carolina "craters" or "Bays" contains fully adequate descriptions of these remarkable depressions, and several hypotheses of their origin have been put forward since Melton and Schriever first advanced their meteoritic hypothesis.[1] The most recent explanation that I have seen attributes their formation to schools of spawning fish![2]

The accompanying aerial photograph (Fig. 1) of a group of 6 craters near Rains, South Carolina, was taken by my late brother Lewin in April, 1934. These craters were studied on the ground by him, my brother Moreau, two friends, and myself. We went to search for them in a car and found them almost as incon-

*Read at the Ninth Meeting of the Society, 1946 September.

FIGURE 1

AN AERIAL PHOTOGRAPH OF A GROUP OF 6 "CRATERS" OR "BAYS" NEAR RAINS, SOUTH CAROLINA, TAKEN BY LEWIN BARRINGER IN APRIL, 1934

spicuous on the ground as they had been spectacular from the air. This circumstance was emphasized by the fact that the aerial photograph afterwards disclosed a seventh crater, bisected by the road, which we crossed 20 times, going and coming, without being aware of its presence! It is no wonder that the relationship and the symmetry of the "Bays" were not noticed before the advent of the airplane! We ran a dip-needle survey on the second of the group, as numbered from top to bottom on the panoramic photograph. The survey indicated a magnetic high at the southeastern rim, where one would expect it to be on the meteoritic hypothesis, but the variation was well within the limits of error. A group from the University of North Carolina afterwards studied the same craters and found the same high. Nevertheless, as a result of our findings, and lack of findings, as well as subsequent evidence, I feel that the meteoritic hypothesis of origin must overcome certain objections in addition to those raised by Watson.[3] Some of these objections have been raised before; at least one I believe to be original. Taken together, they seem to me to be almost insuperable.

In the first place, as has often been pointed out, there are no meteorites directly associated with any of the typical craters on the South Carolina coastal plains. The fact that we found none in a week's search has little significance. The fact that none has been found in 300 years of cultivation, in a region where even stones of any type are extremely rare, is certainly significant. I have often flown over the craters, and it is easy to identify little ones 20 to 40 feet long, lying in plowed fields. If meteorites had made the big craters and had been buried too

deeply to become accidentally exposed, could this fact have been true of those forming the little craters, on the meteoritic hypothesis? Surely some fragment would have turned up; especially since the Melton and Schriever hypothesis was advanced, the local inhabitants have been very much on the lookout for meteorites; *e.g.*, we were driven 10 miles to see a piece of bauxite that was thought to be meteoritic!

In the second place, can one visualize an impact crater a mile long in diameter where the strata a few feet under the surface are undisturbed? Yet one of the Carolina "Bays" was intersected by the Intra-Coastal Canal, and the strata in the surrounding ground can be seen to continue unbroken below the crater, a mere foot or two under the surface. Does not this fact prove a shallow surface formation rather than a filled-in meteoritic crater?

In the third place, should not the smaller craters have been relatively more "filled-in" than the larger? At Odessa, Texas, the smaller craters had completely disappeared and were found only in connection with work on the main crater. There is, however, no such difference between the relative depth of the smaller and larger Carolina craters.

Finally, the Rains, South Carolina, group shows a symmetry that can hardly be attributed to a chance distribution of a swarm of masses in space. It will be noticed (Fig. 1) that the largest of these craters falls roughly in the center of the group and that 2 smaller ones flank it on either side, with the 2 smallest ones on the outside. Furthermore, a single straight line will bisect each of 5 craters at the center, and miss the center of the sixth by only a few hundred feet. The rims of the craters touch each other in 3 cases, and just miss touching in the other 2. Even on the ingenious suggestion that the Siberian craters were formed by negative matter,[4] which accounts for the absence of meteorites, can such symmetry be explained? Are not the statistical odds rather heavy against 6 bodies coming in abreast, each separated from its neighbors just far enough to prevent the resultant craters from overlapping? I realize, of course, that this distribution is not typical of the Carolina craters, tho there is a greater tendency for their rims to touch than one would expect on the hypothesis of a chance distribution.

To sum up: the absence of any meteoritic find indisputably connected with the Carolina craters; the undisturbed condition of the immediately underlying strata; the continued existence of smaller craters, while the larger ones are so nearly "filled-in"; and, finally, the curious distribution of the Rains craters, all seem to me to argue rather strongly against the meteoritic hypothesis of the origin of these extraordinary formations.

References

[1] F. A. Melton & William Schriever, "The Carolina 'Bays' — Are They Meteorite Scars?," *Jour. Geol.*, **41**, 52-66, 1933; F. A. Melton, "The Origin of the Carolina 'Bays'," *Discovery*, **15**, 151-4, 1934; *v.* also Douglas Johnson, *The Origin of the Carolina Bays*, xiv + 341 pp., Columbia Univ. Press, 1942.

[2] Chapman Grant, "Biological Explanation of the Carolina Bays: with Biographical Sketch," *Scientific Monthly*, **61**, Supplement 8, 443-50, Dec., 1945.

[3] Fletcher Watson, Jr., "Meteor Craters," *P. A.*, **44**, 2-17, 1936.

[4] Lincoln La Paz, "Meteorite Craters and the Hypothesis of the Existence of Contraterrene Meteorites," *C.S.R.M.*, **2**, 244-7; *P. A.*, **49**, 99-102, 1941.

Atomic Bombs, the Tektite Problem, and "Contraterrene" Meteorites

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ABSTRACT

Silica debris reported from the explosion of atomic bombs may solve the problem of tektites and support the hypothesis of "contraterrene" meteorites.

The origin of tektites and of silica and Darwin glasses, discussed in several papers published in *C.S.R.M.* and elsewhere, is still an unsolved mystery. Dr. L. J. Spencer's hypothesis of meteoritic explosion-craters suggests a cosmic origin for these things. The intense heat of the impact of the cosmic body with terrestrial rock (or sand) vaporizes the cosmic body as well as a large mass of the terrestrial rock; their siliceous content assumes the form of tektites, or various kinds of silica glass, while the metallic content (mainly iron and some nickel, in the case of a meteorite) falls down in a fine spray. There are, of course, many puzzling details of structure, composition, and form to account for, but there seems to be a general agreement in certain characteristics of specimens found on different continents; *e.g.*, "the dominance of potash over soda," "usually accompanied by a predominance of ferrous oxide," in contrast with most known terrestrial rocks and glasses[1]; their index of refraction, $\mu = 1.48$ to 1.49 (while ordinary glass has a value of 1.5, and, we may add, fused quartz, about 1.458); their melting point, 1400° C. (as against 1250° C. for artificial glass[2]); their radium content, near about 1.00×10^{-12} gram per gram, agreeing with that of granites.[3] These common characteristics point towards a common origin for these specimens.

The absence of meteorite craters in the vicinity of tektite and silica finds has been explained as due to obliteration by the usual processes of terrestrial denudation or of sand drift, but the failure to detect iron in quantity has ruled out the hypothesis of "terrene" meteoritic impact, and has given color to the hypothesis of "contraterrene" meteorites.[4] "Contraterrene" matter (whether as meteorite or comet), tho theoretically conceivable, can be "detected" only from explosions caused by its sudden annihilation when it comes into contact with terrene matter.[5] The only phenomena that can bear a near enough comparison with such destructive effects as would accompany the fall of a "contraterrene" meteorite are the explosions from the bursting of atomic bombs, in which the temperatures evolved are reported to be as high as those present in the interiors of stars, giving rise to the artificial transmutation of elements, generally from lower to higher atomic weights, strong radioactivity, and the emission of γ-rays.

Silica glass is said to have been found as debris from the wreckage of Hiroshima and Nagasaki in Japan, and possibly also in New Mexico. "The Report of the British Mission to Japan" (published by H. M. Stationery Office, 1946) deals mainly with the damage done to structures—both human and material. American meteoriticists may possibly be permitted to obtain samples of the silica-glass debris formed in New Mexico from the trial bomb dropped there (if the reports about the formation of the substance may be assumed to be correct). If so, it would be worth while for them to examine the physical and chemical properties of the substance and to see how they compare with the data accumulated with regard to tektites and silica glasses, referred to previously. In case there is a

general agreement, some of the mystery surrounding the origin of tektites would disappear, and "contraterrene" matter would acquire something of an "objective reality."

REFERENCES

[1] H. Otley Beyer, *C.S.R.M.*, **2**, 157-63; *P. A.*, **48**, 43-8, 1940.
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[3] V. S. Dubey, *Nature*, **132**, 678, 1933.
[4] Lincoln La Paz, *C.S.R.M.*, **2**, 244-7; *P. A.*, **49**, 99-102, 1941.
[5] V. Rojansky, *Astroph. Jour.*, **91**, 257-60, 1940.

1946 December 10

On the Temperatures of Meteorites in Interplanetary Space

There seems to be considerable misapprehension concerning the probable temperatures of meteorites in interplanetary space; *e.g.*, the statement is frequently made that the temperature of a meteorite just before it collides with the Earth's atmosphere must be extremely low—possibly not far from absolute zero. It is difficult to see how this misconception originated. It readily follows from the Stefan-Boltzmann law of radiation that the so-called "black-sphere" temperature, "which is approximated by a meteorite," is given by the formula

$$T = 277°/\sqrt{R},$$

where T is the absolute temperature (K.) of the body in degrees centigrade and R is its distance from the Sun in astronomical units.[1] According to this formula, the temperature at the Earth's distance from the Sun (1 a.u.) is 277° K. = +4° C., which is a long way from absolute zero, being, in fact, several degrees higher than the temperature of freezing water! Even at the mean distance of the most remote known planet, Pluto (39.46 a.u.), the "black-sphere" temperature is 44° K. = —229° C.—which is still considerably above absolute zero (—273° C.).

If the thermal behavior of a meteorite is at all comparable to that of a small black sphere, it does not appear likely, then, that the temperature of a meteorite, anywhere within the confines of the known planetary system, is only a trifle higher than absolute zero; it is probably much higher than that, everywhere.

F.C.L.

Missing Meteorite Found in Eire: Limerick County

Under the heading, "Missing Meteorite Found in Eire," a clipping from *The New York Times* of 1947 January 28 reads as follows:

"DUBLIN (Canadian Press).—Lost to scientific research for more than 130 years, the largest meteorite known to have fallen in the British Isles has reached the National Museum here. It was part of a meteoritic shower which fell in the Patrickswell and Adare district of County Limerick in 1813. It was found originally by a resident of the area who ultimately sold it with a pile of scrap metal. The meteorite weighs a trifle more than 59 lb. and has the appearance of bronze."

The coördinate number of *Adare* is 0088,526. According to Prior's *Catalogue of Meteorites*, 99-100, 1923, the *"Limerick County, Ireland,"* fall occurred 1813 Sep. 10, 9 A.M.; it is known also under the synonyms *Adare* and *Faha;* and it

[1] *V.* Russell, Dugan, & Stewart's *Astronomy*, **2**, §612, 540, 1926, and F. G. Watson's *Between the Planets*, 149-50, 1941.

is a veined gray bronzite-chondrite (Cga). "A shower of stones fell after detonations, one of 17 lb. at Scagh, several smaller ones near *Adare,* one of 65 lb. at Brasky, and another of 24 lb. at *Faha.* . . 8½ kg. in Oxford University, 1 kg. in Tübingen University," and smaller specimens in the British Museum (Natural History).

First Notice of the Tenth Meeting of the Society

The Tenth Meeting of the Society will be held on Wednesday, June 18, and Thursday, June 19, 1947, in connection with the meeting of the Pacific Division of the American Association for the Advancement of Science, in San Diego, California. The afternoon session of June 19 will be a joint session (the subject of which will be announced later) of our Society and the Astronomical Society of the Pacific.

Members of the Meteoritical Society are hereby requested to send the undersigned, at their earliest opportunity, and by May 1 at the latest, the titles and abstracts (in form for publication in *C.M.S.*) of any papers that they may wish to present, or to have presented, at the Tenth Meeting.

JOHN A. RUSSELL, *Chairman, Program Committee for the Tenth Meeting*

Department of Astronomy, University of Southern California,
Los Angeles 7: 1947 March 1

President of the Society: ARTHUR S. KING, Mount Wilson Observatory, Pasadena 4, California

Secretary of the Society: OSCAR E. MONNIG, 1010 Morningside Drive, Fort Worth 3, Texas

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Eclipsing Variables: Contribution No. 21 from the Princeton University Observatory contains an interesting dissertation by Frank B. Wood on nine eclipsing variables. Three methods of observation were used, photoelectric, visual, and photographic. The visual observations were made with a polarizing photometer attached to the Princeton 23-inch refractor. The photoelectric work was done with the 36-inch reflector and photoelectric photometer of the Steward Observatory. The photographic plates were also taken at Tucson with the Steward reflector, images being out of focus. Conclusions arrived at for the nine variables studied are as follows:

AG Virginis: The most striking feature is the large asymmetry shown in the light curve, undoubtedly real and not a periastron effect.

AR Lacertae presents a system in which one of the components is intrinsically variable, with the variable component of G5 spectral type, and a density of 0.23 ⊙. There is also evidence of a sudden change of period in recent years.

TX Ursae Majoris: There is evidence that the secondary is displaced, indicating orbital eccentricity, with a rotation of line of apsides suggested by the two residuals of the primary.

VV Orionis: No indication of any variation of period. The star offers an excellent opportunity for study of the limb darkening of early B stars.

R Canis Majoris: The change in period first indicated by Dugan is confirmed, and a further shortening of the period is indicated. No trace of any "hump," as noted by earlier observers, is found, and the orbit is undoubtedly circular. The fainter component of the system is obviously a very peculiar star.

SV Camelopardalis: The eclipse is shown to be annular rather than total, and the period appears to be subject to variation. The light curve presents a strange hump, similar to the one found earlier at Harvard on the light curve of R Canis Majoris.

ST Persei also shows evidence of a sudden change of period. It is pointed out that since the variable itself has a close visual companion, depth of minimum can be accurately observed only with large instruments, in which the light of the companion is not involved in the measures.

RY Persei: There is no evidence of a change of period. The usual Algol system is indicated; the eclipse of a small bright component by a larger fainter one.

VZ Hydrae: No outstanding peculiarities in the visual curve are noted, which fact alone makes it perhaps the most unusual of the stars here studied.

Of the nine systems discussed, three show total eclipses at primary, four annular, and two partial.

Figures illustrating the observed light curves are shown in the original publication for each variable.

Recurrent Nova Sagittae (1913): In these Notes for October, 1946, attention was called to the second observed outburst of the 1913 nova in Sagitta, as detected by Dr. Kurt Himpel on the night of June 28, 1946, when he was fortunate to catch the star on the rise to maximum.

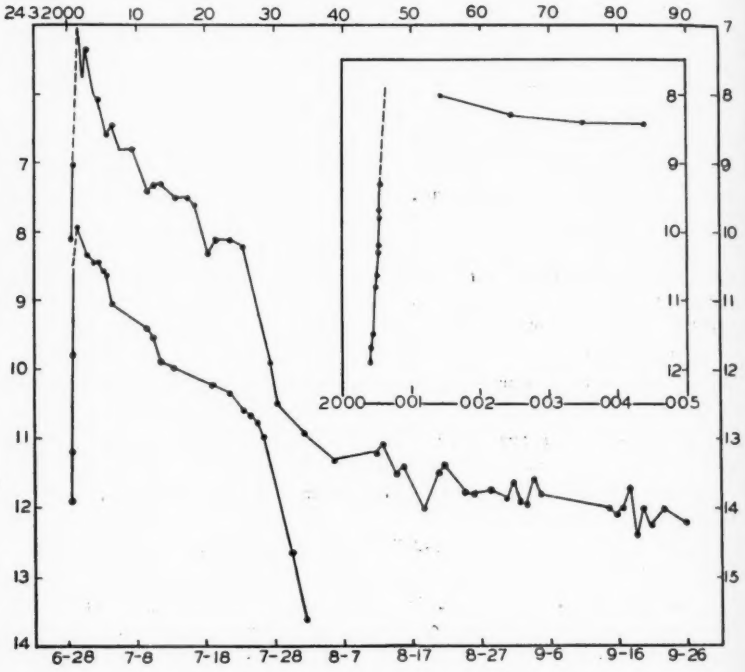
A reprint recently received from the Heidelberg Observatory (Vol. 14, No. 9), contains not only the actual estimates made by Dr. Himpel on the night of the outburst, but photographic and visual observations made since then by Lohman and Miczaika, respectively.

Himpel's visual observations indicate an increase in brightness from magnitude 11.9 to 9.3 over an interval of four hours, and it is evident that maximum brightness was attained on June $28^d.7$ (U.T.), probably near magnitude 7.2. On June 29, the star had already begun to decrease in brightness, magnitude 8.0, and from then on a gradual diminution took place until July 26 at magnitude 11.0, after which the decrease was decidedly more rapid. On August 1, the nova was observed at visual magnitude 13.6.

Mrs. Mayall has recently collated the photographic observations from Harvard plates, and when Lohman's 15 photographic observations covering 34 days have been reduced to the same scale as the Harvard observations—the International Photographic Scale—and combined with these, we have a fairly complete record of the light changes until September 25, 1946, when the nova was

hovering around photographic magnitude 14.

In the accompanying figure are shown the photographic light curve above the visual, and, in greater detail, the visual observations made during the first few nights after detection.



LIGHT CURVES OF NOVA SAGITTAE, 1913, IN 1946
(Upper, photographic; lower, visual; inset, visual.)

Special Variables: R Coronae Borealis is back to nearly normal maximum brightness, magnitude 6.4, after a rather rapid increase from minimum at near the 11th magnitude. S Apodis is, as was suspected, well below maximum brightness, fainter than the 14th magnitude late in January. These, with RY Sagittarii, reported as faint in January, bring to three the number of variables of the R Coronae Borealis type which were below normal maximum brightness at the same time SU Tauri, the fourth variable of this type on the AAVSO observing list, has been at normal maximum brightness for the past two years, save for a slight dip of short duration in January, 1946.

SS Aurigae passed through a broad type maximum early in February, and U Geminorum through a narrow maximum late last December. SS Cygni was at maximum (No. 356) early in February—slow rising, broad, type.

AAVSO Spring Meeting: The 1947 Spring Meeting of the Association will be held, by invitation of Professor Leah B. Allen, at Hood College, Frederick,

Maryland, on May 16 and 17.

Observations received during January and February: A total of 6,752 observations—3,378 in January and 3,374 in February, were contributed by 65 observers, as follows:

Observer	January—1947—February No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	January—1947—February No. Var.	No. Ests.	No. Var.	No. Ests.
Ahnert, P.	..	..	38	184	Macris	13	57	..	..
Ashbrook	..	..	5	39	Mallas	26	285	..	..
Bicknell	13	111	11	36	Matthews	8	49	23	217
Blunck	6	6	20	20	Mount	4	11	7	28
Bogard	12	32	13	37	Oheim	67	70	..	..
Boone	..	..	2	2	Oravec	32	126	46	192
Brennan	..	..	1	1	Parks	24	24	31	42
Buckstaff	..	..	10	12	Peltier	111	150	122	176
Chandra	94	117	195	314	Raphael	..	..	22	71
Chassapis	55	148	10	17	Reeves	..	..	2	3
Cilley	30	100	35	100	Renner	68	88	..	..
Cousins	8	16	..	..	Robbins	8	42	..	..
Cragg	1	6	..	..	Rosebrugh	24	104	18	137
Damkoehler	4	8	4	13	Segers	..	..	15	67
Elias	39	79	26	41	Sherman	11	22	10	40
Escalante	7	16	82	97	Sill	..	..	25	27
Fernald	302	550	264	505	Slemaker	10	40	19	42
Focas	45	53	11	13	Smith, B. A.	1	3	..	..
Garneau	15	15	21	21	Smith, S. M.	5	7	4	12
Hale	..	..	10	10	Stahr	3	4	3	7
Harris	28	28	7	7	Tarbell	..	..	3	13
Hartmann	163	165	141	144	Taboada	37	37	49	49
Howarth	17	17	23	23	Wade	3	5	..	..
Hukill	4	38	4	52	Webb	12	14	..	..
Itzigsohn	46	111	..	..	Weber	..	..	44	44
Kelley	4	20	3	11	Weintz	13	46	11	26
Kelly	13	13	11	17	Welker	14	17	28	45
Kilby	13	17	4	4	Welles	8	13	5	26
Kitley	41	47	41	100	Whitmarsh	3	5	2	3
Knott	..	..	2	3	Weitzenhoffer	..	..	3	10
de Kock	87	395	74	190	Zirin	34	34	..	..
Koons	..	..	17	18					
Liller	..	..	18	18	65 totals		3,378		3,374
Luft	4	17	4	54					

March 15, 1947.

Comet Notes

By G. VAN BIESBROECK

There is little to report this month in regard to comet activity. COMET 1946 *k* (BESTER) was observed here last night at low altitude in the western sky. It appeared as a small nebulosity not brighter than 12th magnitude but that figure is uncertain on account of the unfavorable conditions. This will terminate the present visibility of the comet which has been well followed since its discovery on 1946 November 1. For a couple of months this object will remain behind the sun and not until May will there be further opportunity to observe it as it emerges from the sun in the morning sky. It will however have lost in brightness by that

time but large telescopes will be able to reach it for several months afterwards as shown by the following ephemeris computed by J. Bobone of the Cordoba (Argentina) Observatory:

EPHEMERIS 1947.0

1947	α h m	δ ° ′	Mag.
May 7	1 43.7	+25 35	12.2
15	46.8	27 59	.2
23	49.6	30 27	.3
31	51.9	32 59	.3
June 8	53.6	35 36	.3
16	54.4	38 18	.4
24	54.1	41 7	.4
July 2	1 52.3	+44 3	12.4

PERIODIC COMET SCHWASSMANN-WACHMANN I (1925 II) continues to remain very faint. In the *Publ. Ast. Soc. Pacific,* Vol. 59, p. 30 (1947), S. B. Nicholson calls attention to the fact that the bright outburst of the comet a year ago (*Popular Astronomy,* **54**, 155, 1946) coincided with the presence of a giant spot on the sun. He urges further observations to discover whether the present maximum of sunspots will bring about more brightening up of the comet. So far this season's appearance has been one of the faintest on record. The object is however still well observable in Gemini and should be further watched. It will be found exactly in the position predicted by P. Herget's ephemeris in *H.A.C.* 777.

EPHEMERIS 1950.0

1947	α h m	δ ° ′
April 7	6 16.3	+29 29
13	19.3	29 18
21	22.8	29 8
29	26.7	28 58
May 7	31.0	28 47
15	6 35.7	+28 37

COMET 1946 *h* (JONES) is now very well observable in the second half of the night. Though losing in brightness it probably will be followed for several months with larger telescopes. The brightness is close to the value predicted by L. E. Cunningham's ephemeris in *H.A.C.* 772.

EPHEMERIS 1947.0

1947	α h m	δ ° ′	Mag.
April 5	19 58.1	+22 58	12.1
13	20 3.0	25 58	12.4
21	6.5	28 54	12.6
29	8.4	31 44	12.8
May 7	8.6	34 26	13.0
15	7.2	36 58	13.3
23	20 4.0	39 17	13.5
31	19 59.1	+41 20	13.7

The search for the expected PERIODIC COMET GRIGG-SKJELLERUP has not met with success so far. The region was scanned here several times but no trace of the presence of the comet could be found. Unless there is a large deviation in the prediction the object must still be very faint. It is now moving rapidly in the

western sky so that it will presumably not be recovered before perihelion passage on April 20. The search will have to be resumed in May when the comet will be in good position in the morning sky and is expected to reach 9th magnitude.

Williams Bay, Wis., 1947 March 12.

SUPPLEMENTARY NOTE

V. M. Slipher, Director of the Lowell Observatory (Flagstaff) reports the recovery of COMET GRIGG-SKJELLERUP by H. L. Giclas:

1947 March 11.140 U.T. $5^h 19^m 13^s.6$ $-31° 3' 53''$
March 12.145 U.T. $5^h 16^m 9^s.4$ $-31° 2' 40''$
Magnitude 11. Diffuse

The brightness corresponds to the expected value but from the position it appears that the comet will reach perihelion three days earlier than the date April 20 predicted by F. R. Cripps. This locates it more than five degrees farther south than expected and adds to the difficulty of observation from northern stations. In a few days the comet will be lost temporarily, passing between the sun and the earth, but in May it should become easily observable.

March 13.

General Notes

Dr. G. N. Neujmin, prominent in astronomical circles in Russia for many years, died on December 17, 1946.

Dr. Frederick C. Leonard, Professor of Astronomy, University of California, Los Angeles, will give a combined course in astronomy and meteoritics and a course in mathematics in the Summer Session of the University of New Mexico, Albuquerque, June 9 to August 6, 1947. Dr. Leonard is a Research Associate of the Institute of Meteoritics of the University of New Mexico.

Dr. Seth B. Nicholson, Astronomer in the Mount Wilson Observatory, will give a course in elementary astronomy and one in general astronomy during the First Summer Session of the University of California, Los Angeles, June 23 to August 2, 1947, while Mr. Paul E. Wylie, Lecturer in Astronomy, University of California, Los Angeles, will give a course in elementary astronomy and one in celestial navigation during the Second Summer Session on the Los Angeles campus, August 4 to September 13, 1947.

National Geographic Society-Army Air Forces 1947 Solar Eclipse Expedition

This expedition to Brazil for the eclipse of May 20 is being organized on a large scale. Eleven distinct lines of technical investigation will be undertaken, with two or more persons engaged in each one.

A group of thirteen scientists will depart from the Washington National Airport on April 1, on a three-day itinerary to Rio de Janiero by way of Puerto Rico and Natal. Five other members of the Society's staff will leave by boat

on the same day. Four members of the National Broadcasting Company will leave by air on May 10. In addition a number of military personnel will fly to Brazil in time for the eclipse.

The eclipse camp will be located near Bacayuva, approximately 400 miles due north of Rio de Janiero, very near the center line of totality. The eclipse here will be of nearly four minutes' duration.

The air forces in addition to transporting personnel will transport approximately 16 tons of food and 25 tons of equipment.

Among the cooperating agencies are the Georgetown, Yerkes, Lick, and United States Naval Observatories. A total of 73 persons will be present at the camp and 15 aircraft will be used in the project.

The Rittenhouse Astronomical Society of Philadelphia held its monthly meeting at the Franklin Institute on March 5, 1947. The speaker for the meeting was Dr. Cecelia Payne-Gaposchkin, Phillips Astronomer, Harvard University. The topic of the address was the problem of "Pulsating Stars."

Yerkes Observatory Reorganization

At a meeting of members of the Yerkes Observatory on March 25, 1947, Dr. Otto Struve outlined to the staff a plan for expansion and general reorganization of the Department of Astronomy of the University of Chicago, which includes the Yerkes Observatory and the personnel of the McDonald Observatory of the University of Texas.

Under the contemplated plan, which will go into effect on July 1, 1947, Dr. Struve will guide the policies and lay the broader plans for the Department of which he is the Chairman. Among other recommendations to the University of Chicago and the University of Texas, he proposes the following appointments:

That Dr. Gerard P. Kuiper be made Director of the Yerkes and McDonald Observatories, with Dr. W. A. Hiltner continuing as Assistant Director; that a theoretical section be created under the supervision of Dr. S. Chandrasekhar, who will continue to reside at Williams Bay; that Dr. W. W. Morgan be named Managing Editor of the *Astrophysical Journal;* and that the Chicago teaching section be revived under T. L. Page.

Dr. Struve will reside at Williams Bay, Wisconsin, and at Mount Locke, Texas.